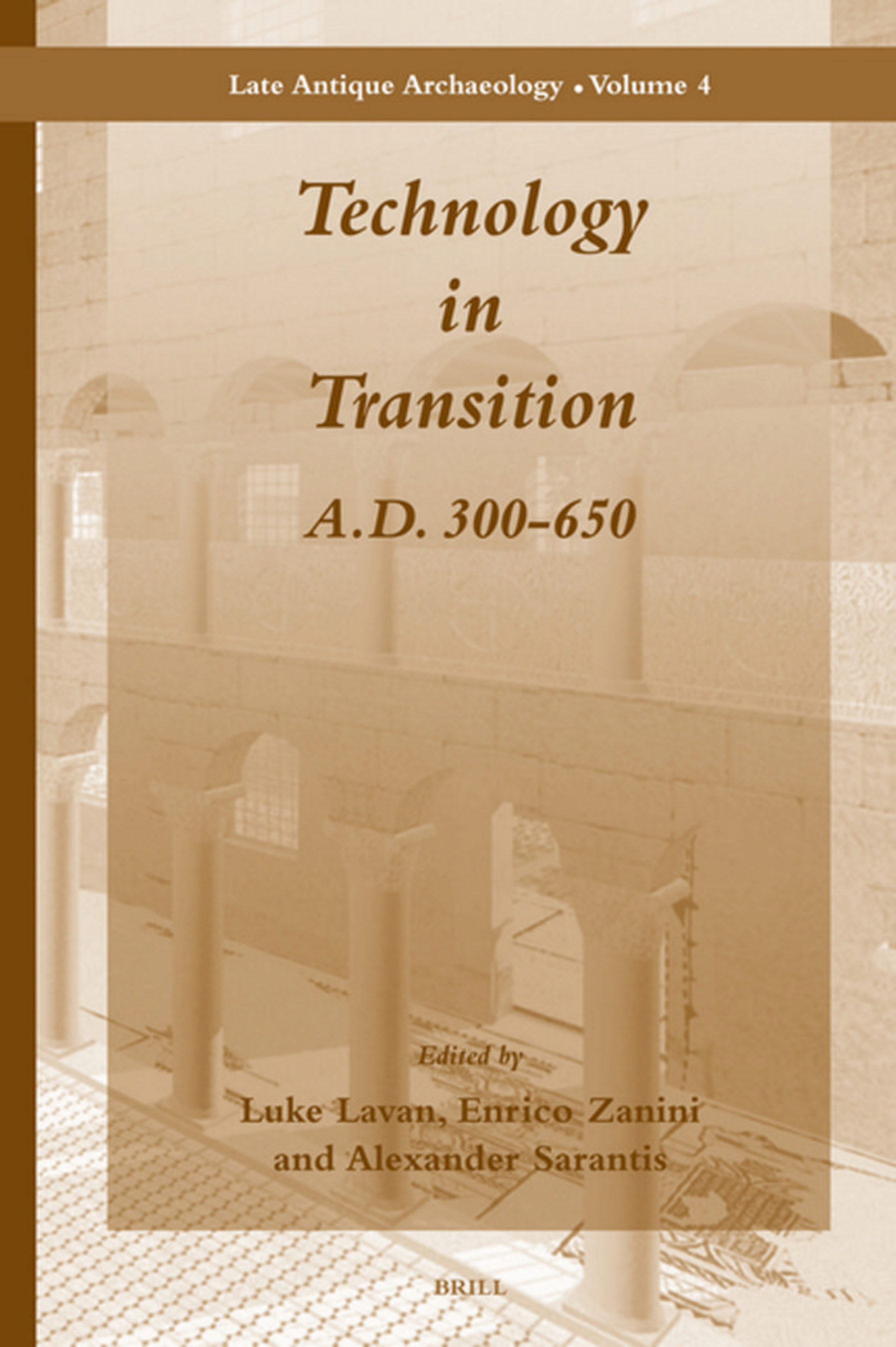

Late Antique Archaeology • Volume 4

Technology in Transition

A.D. 300–650

Edited by
Luke Lavan, Enrico Zanini
and Alexander Sarantis

BRILL

TECHNOLOGY IN TRANSITION
A.D. 300–650

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EDITED BY

LUKE LAVAN,
ENRICO ZANINI
AND
ALEXANDER SARANTIS

WITH THE ASSISTANCE OF
INE JACOBS, DIRK BOOMS, BART DE GRAEVE

BRILL

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INTRODUCTION

EXPLAINING TECHNOLOGICAL CHANGE: INNOVATION, STAGNATION, RECESSION AND REPLACEMENT

Luke Lavan

Abstract

This paper will probe the dynamics responsible for technological change in Late Antiquity and the Early Middle Ages. Examples of innovation will be considered, both those which were widely adopted and those that, though technically impressive, were not exploited in the period. Technological 'stagnation' and recession will be explored, as will examples of the exceptional survival of Roman technology in the Early Medieval period, as well as the adoption of simpler technological solutions during this time. The article seeks to identify possible causes of these transformations, concentrating on the role of the State, military pressure, economic change, elite patronage and cultural choice.

Introduction

The purpose of this book is to investigate the technology of the Mediterranean world between A.D. 300 and 650. However, merely to enumerate and describe technologies during Late Antiquity is not enough. Some attempt needs to be made to consider large-scale technological change. This is what I will attempt to explore in this paper, at a more general level than the paper of T. Mannoni, who focuses on specific circumstances leading to technological change within artisanal workshops. I will try to ask why technologies of the period became more or less 'complex' in relation to other periods. In doing so I will seek to address questions of long-term change which often trouble lay visitors to Roman and Dark Age rooms in provincial museums: notably, "why did Early Medieval people 'forget' the inventions of the Romans?".

Such questions of long-term change raise issues of cultural comparability: is it possible to compare, even measure, the technologies of different societies, in different periods? A cultural perspective would stress that technologies often relate to specific local domestic or work-

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shop traditions, unaffected by or insensitive to external circumstances, making comparison difficult. Yet in highly complex societies, such as the Roman Empire, technology is more than a manifestation of domestic, workshop and cultural practices: it can be affected by wider forces, such as market pressures, political imperatives and military necessity, which tend to encourage greater productivity. This is not to say that a 'cultural' perspective is of no value: many technological choices can be explained by cultural choice rather than economic pressures or military competition. But a cultural perspective on technology is better adapted to the Early Middle Ages than to the Roman world of the 4th–6th c. A.D. In fact, the transition between Late Antiquity and the Early Medieval period requires one to draw on both explanations of technological change, as political and economic structures retreated and cultural forces asserted themselves more strongly.

Consequently, this paper will be written mainly from a 'teleological' viewpoint: that is, it investigates directional change, employing such terms as 'innovation', 'stagnation' and 'recession'. This perspective assumes that not all technologies are equally effective in assuring a productive outcome, and that some technologies are more complex than others. It also assumes that, in terms of both productive effectiveness and technological complexity, there can be a move from simple to complex and vice versa, though increased productive effectiveness is not always the result of increased technological complexity. Nevertheless, in this paper, I will try to be sensitive to those technological changes which relate best to cultural traditions and thus cannot easily be set within a scheme of development from simple to complex.

Technology and Technological Change in Late Antiquity

This book appears at a time when most scholarship has moved away from the view, held by L. White Jnr. and M. Finley, that the technology and economy of the Roman world was characterised by stagnation and pre-industrial primitivism, hampered by amongst other things, elite distaste for commerce, and the use of slave-labour rather than a motivated free workforce.[1] This view, which was prevalent as late as 1980, has been challenged by 30 years of archaeological work, which have produced an image of a dynamic society in which there was both considerable economic growth and technological innovation, as well as much 'transfer' of existing technologies.[2] Far from being a stagnant precursor to Medieval technical achievement, Roman society at its height seems to have been equivalent in economic and technological complexity to 17th or even early 18th c. Europe, casting its shadow over most, and perhaps all, of the Medieval world. In this book, E. Giannicheda restates a primitivist view in relation to the production of metal (187–88). However, many other indicators of economic growth (rural settlement expansion and traces of exchange) and technological prowess (as in glass, ceramics or civil engineering) point to the grandeur of the Roman civilisation, which seems only to stand comparison with 17th c. China, India or Europe. For the East Mediterranean, the peak of the ancient economy comes in the late 5th–early 6th c. A.D., when rural settlement increased in density and expanded into areas never cultivated before, and rarely since. Amphorae and other ceramics now point to a major trading axis between Africa and the Near East, relating to commercial rather than political exchange.[3]

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[1] Finley (1965), White (1979).

Still, a shadow lingers over the technology of Late Antiquity. The late antique period has suffered particularly from the label of 'stagnation', and also from the suggestion that the dislocation of the Medieval period can be sought in changes within Late Antiquity. This is particularly tempting given that Max Weber ascribed so much importance, in the emergence of capitalism, to the eclipse of Catholic modes of thought.[4] No matter how outmoded Weber might be, could not the ruin of Rome be explained by the adoption of an unworldly religion? One might have expected the recent growth in archaeological fieldwork to have excluded such views, as it has for the Principate, but this is only partially the case. Some scholars such as S. Kingsley, studying maritime technology, or M. Decker studying irrigation, are quick to identify innovation in the period. But others still stress technological decline within Late Antiquity: most notably A. Wilson, who recently suggested that Christian indifference towards dirt and the ills of the body might have led to a deterioration of urban aqueducts and sewage systems in the 5th–6th c.[5, 6]

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[2] Greene (2000), also with further articles by the same author listed in the bibliographic essay (6). See also papers in Lo Cascio (2006) and Oleson (forthcoming).

[3] On rural settlement see papers in Bowden and Lavan (2004), especially those by Chavarría-Lewit and Baird. For late antique trade see Kingsley and Decker (2001).

[4] Weber (1904–05).

Much of this disagreement over the nature of late antique technology can be explained through differences in periodisation, visible within this book. For many Italian scholars, who tend to begin Late Antiquity in A.D. 476, the era is seen as one of stagnation and decline. For those working in the East Mediterranean and in some other regions, the same period is one of expansion and vitality, in its technology as much as in other domains. These 'Eastern' scholars often define Late Antiquity as running from Diocletian (A.D. 283) to the fall of Maurice (602) or to the surrender of Egypt (645). In their view, the Late Antique world in both East and West, is to be separated from the Early Medieval world, which began at different times in different places during the 5th–7th c. This perspective tends to consider the East and Central Mediterranean to be the 'heartland' of Late Antiquity. Italy is now peripheral, as part of a great 'shift' of the core of Western Civilisation to the south and east, in which Arabia, Axum and Yemen now come into view.

The latter view has informed much of the conception of this book, if not the opinions expressed in individual papers. From this perspective, the technological achievement of Late Antiquity (4th–6th centuries) is broadly positive, if not quite as glorious, when compared with the Principate. It seems fairest to view the technological development of Late Antiquity not from the 1st c. A.D. but from the difficult years of the later 3rd c., when a number of technologies seem to have been disrupted or discarded. The late antique period is from this point of view generally a period of economic and technological recovery. In contrast, the Early Medieval period, in Europe or Byzantium, is one marked by the simplification and disappearance of many technologies, within profoundly simplified economic and political structures.

Technological changes are also apparent which do not relate to general chronological processes: sometimes technological innovation, stagnation and recession co-exist together—making up one of the most

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[5] Kingsley (forthcoming); Decker (forthcoming); Wilson (2000).

[6] A clear late antique Christian understanding of urban hygiene does exist in Joh. Chry. *Hom. in Eph.* 10. "The drains in our streets we take care to keep unobstructed. We cleanse our sewers with poles and drags, that they may not be stopped, or overflow, but the canals of our bodies we do not keep clear, but obstruct and choke them up.... To obstruct the sewers is to breed a pestilence; but if a stench from without is pestilential, that which is pent up within the body, and cannot find a vent, what disorders must it not produce both to body and soul?"

fascinating aspects of the period. Such changes can be related to many different contextual factors, such as the influence of external powers, the arrival of new ethnic groups within the empire, or socio-economic changes internal to Mediterranean society. Thus, any explanation of technological change within the period must be multi-faceted, and take into account both chronology and contextual circumstances. An overarching concept of 'stagnation' or 'decline' cannot accurately describe technological change in this era. More sensitive models are needed, which incorporate empirical archaeological data, and allow us to separate out different processes, regional trends, and sub-periods.

Conceiving of Technology

In studying technology one has to make a choice. What definition would be most suitable? Many definitions are available, ranging from knowledge of tools and craft techniques, to the study of machines and tools, or of engineering techniques.[7] In the broadest sense, all of human culture represents technology: both anthropologists and archaeologists have stressed the ecologically adaptive capacities of human culture, present in Leslie White's definition of culture as "man's extra-somatic means of adaptation" [to his environment].[8] Yet this reasoning, if applied to define technology, seems to exclude adaptation to problems that are of man's own making, which have little or no direct relationship to the environment: such as technologies which seek to build and sustain culturally specific political and social relationships, or concern the aesthetics of literary culture and art. Thus the definition of technology used in this paper encompasses all mental and technical processes which humans use to solve the range of problems they face or create for themselves. Such a definition, although vast, allows one to include not only agriculture, extraction, production or transport, but also administration.

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[7] Webster's dictionary of 1913 privileges "industrial science" and "knowledge of the industrial arts", whilst the Concise *OED* 8th ed. of 1980 has "use of the mechanical arts and sciences". More typical now is one of the many definitions offered by www.word.iq.com (last accessed October 2007): "...the development and application of tools, machines, materials and processes that help to solve human problems." For academic discussion see Sigaut (1994).

[8] White (1959) 8, followed notably by the archaeologist Binford (1972).

Having said I wish to investigate directional technological change, I do not wish to embrace the modern conception of technological history as being the story of cumulative progress led by discovery. This idea falls down with even a preliminary examination of the technological change in the period. Late Antiquity of course had its fair share of inventors, as does any age. Some of them were very creative: such as the anonymous author of the *De Rebus Bellicis*, who apparently thought he was better placed than the emperor and his generals in deciding the military strategy of the day. His inflatable bridges and ox-powered paddle boats are unlikely to have greatly improved military performance.[9] Yet there were others with a taste for experimentation: through Agathias we hear that the architect Isidore of Miletus got up to far more than building churches for the emperor Justinian: on one occasion he terrorised a neighbour with a lightning machine and an earthquake simulator, based on pumping steam into a system of pans under the floorboards of his victim's house.[10] On a more serious level, as E. Gianichedda describes in this volume (200–201), investigations in Val Gabbia in Northern Italy have revealed that the production of cast iron was known in the 5th–6th centuries, although it was never exploited on a large scale, probably because it was not fuel efficient for the quantities of iron desired.

Inventions of this kind serve to show us, if we had any doubts, that technological innovation through discovery did exist in Late Antiquity, but that it was not a motor for change, out of the context of the needs of the time. There are always new discoveries and ideas in every period. The meaningful study of technology is not the enumeration of inventions, but rather the study of technologies as used. Thus, in common with much other recent scholarship, this paper adopts a contextual understanding of technology, that considers the place of technology within the society which produced it and used it, even if it is still useful to discuss development from simple to complex and vice versa.[11]

There has been much thought amongst historians and archaeologists as to how such a contextual understanding might be achieved, as discussed in a recent review article by K. Greene. At some levels, the study of technological change could probably include the study of language and the gendered social construction of technological concepts.[12] However, for Late Antiquity, the cultural and domestic sphere does not represent the full context for many of the technologies of the period. The existence of an active State, Church and a market economy mean that the fullest context for late antique technology is found in wider society. As this paper will seek to demonstrate: innovations or extinctions of the period can be correlated with major events and influences known from texts and archaeological sources: such as war, the growth of the State and the Church, and the role of markets.

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[9] Hassall and Ireland (1979).

[10] Isidore: Agath. 5.7–5.8.

[11] For contextual studies of technology in archaeology: van der Leeuw and Torrence (1989).

Technological Change Within Late Antiquity

The study of technological change in Antiquity is a soft science, especially on a general level. So many factors are at play that it is not always easy to produce convincing explanations for why change occurs. However, it is possible to describe areas of substantial technological change, that go beyond the fate of one workshop or one profession, and so offer tentative contextual explanations which appear to be connected in time and space. This is what will be attempted in the pages that follow, which describe broad dareas of technological innovation, stagnation and recession, and offer potential causes relating to aspects of late antique society.

Innovation

Innovation encompasses *technology transfer* ('diffusion' when transferred over geographical distances), as well as *invention* (either intended or accidental) which results in new techniques being applied. There appears to be evidence for both technology transfer and invention within the Mediterranean world of the 4th–6th centuries A.D.

Technological changes in administration included examples of diffusion, such as the use of paper from the East (for which Cassiodorus had so much praise), and examples of accident, such as the increased monetisation of exchange caused by the greater spread of small denomination bronze coins.[13] Of outright invention we can find little: except

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[12] Greene (2003).

[13] Cassiod. *Variae* 11.38. Increased monetization: Reece (1984).

Diocletian's failed attempt to regulate prices. However, the expansion of technologies of information management and control brought success in other areas. The increasing use of the codex made data retrieval easier for administrators, being accompanied by an expansion in the development of reference works and advancements in conflict resolution, through the codification and spread of Roman law.[14]

This range of changes can be seen in terms of a positive productive outcome: the increased penetration of the imperial administration. It is possible to see the entire centralisation of the Late Roman State, whereby well co-ordinated and professionalised officials and lawyers reached ever deeper into civic affairs, as representing a technological triumph; certainly, the bureaucrats of Milan and Constantinople achieved a degree of prominence in Mediterranean urban society that no Hellenistic king had ever achieved, and which would not be equalled in the West until the end of the Middle Ages.[15] The motors for the increasing diffusion of efficient administrative practice were obviously the great bureaucracies of Church and State in this period, which provided a large enough monied context for technological efficiency to be valued.[16] Sometimes this is made explicit by contemporary literary sources: the high-pressure praetorian law court at Constantinople, remembered by John Lydus, greatly appreciated its water clock and other timing devices, no doubt as much for their efficiency in limiting speeches as for the wonder they provoked.[17]

Military technology was another major area of technological change in Late Antiquity. Much of this was clearly innovation—perhaps best seen in the Theodosian Walls of Constantinople: these were perhaps the most powerful fortifications ever built in Antiquity, in terms of their scale, depth and strategic complexity.[18] The widespread addition of both the *proteichisma* and pentangular towers to the walls of small cities and fortresses in the East, reveals that innovation in this area spread deeply through society.[19] Late Roman city walls were also supported by sophisticated artillery machines, some new, such as the arrow-shooting ballista, and some already known, such as onagers, but applied to the defence of walls in a manner unprecedented for the Principate.[20] Military innovations were not however confined to fortification. The introduction of styles of helmet that were simpler to manufacture—notably those of the Intercisa type—probably led to their quicker production in imperial arms factories.[21]

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[14] E.g. Roberts and Skeat (1983).

[15] This process is traced by Jones (1940), who saw the prominence and penetration of the Late Roman government in civic life as a negative development (esp. 155).

[16] On Church and State record-keeping see Lane Fox (1994) and Kelly (1994).

[17] Joh. Lydus *Mag.* 2.16.2–4.

[18] Crow (2001) 92.

[19] Smith and Crow (1998). At small fort site of Dichin in Bulgaria: Poulter (1999) 244.

Nevertheless, it is difficult to escape the fact that some changes visible in the technology of warfare (such as the use of lance-bearing heavy cavalry) can be at best described as diffusion from neighbouring peoples. The fact that these peoples could sometimes now defeat Roman forces in pitched battles, provided an obvious reason to take up their technology and methods of fighting. Maurice's military manual, the *Strategikon*, was especially aware that it was necessary to beat the Avars and other enemies by understanding, and if necessary mastering, their style of warfare.[22] Warfare has always produced an important context for innovation, especially when defeat meant not just the loss of some territory, but potential catastrophe, as when facing the large enemy armies of Late Antiquity. But it should be remembered that fighting represented only part of the military strategy of the empire, which was based on the possession of fortifications, filled by a supply system that was far superior to those of all enemies except Persia.[23] Of the northern barbarians, only the Huns and Avars were capable of besieging cities, with siege towers and so forth.[24]

One should not underestimate the decisive advantage that technical knowledge in fortification, supply infrastructure and water transport gave the Roman army. The Hun Onegisius greatly valued a Roman architect whom his people captured: he had the latter construct some baths in the Roman style, which he clearly could not have had otherwise.[25] Conversely, it is interesting to see that Theodosius II interpreted barbarian use of boats in the Black Sea in A.D. 418 as the result of technological treachery: someone must have told the barbarians how to build them, as previously they had not been able to do this.[26] The continued superiority of Roman engineers was again underlined in the 570s when the Avars forced captured imperial architects to construct a bridge over the Danube, in order to allow them to invade Roman territory.[27] Obviously, the resources of the Roman State funded specialised workers in the Eastern army, who were trained to a high level: as E. Zanini shows (389–94) Roman military architects were proud enough to 'sign' their work in inscriptions. The Roman State, in contrast to most of its enemies, was capable of supporting a specific context of high technological achievement, in which both the preservation of technical skill and innovation was possible.

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[20] In particular, the use of onagers is little known before the 4th c.: Marsden (1971) 249–65, and 234–48 for the arrow-shooting ballista.

[21] Lusuardi Siena, Perassi, Facchinetti and Bianchi (2002).

[22] Maurice *Strategikon* ed. and trans. Dennis and Gamillscheg (1981).

[23] Isaac (1992).

[24] See review of this topic by Whitby (forthcoming).

[25] Priscus *frag.* 8.

[26] *Cod. Theod.* 9.40.24 (A.D. 418).

Excellence in civilian building technology was also long related to the political sphere. In the Late Republic and Early Principate, the flowering of Rome, as a political capital provided a powerful motor for large scale building work, as recalled by R. Santangeli Valenzani (436–37). Apocryphal anecdotes suggest that emperors resisted technical innovation for political reasons. Yet archaeological observations of monumental buildings tell a different story. At Rome, the patronage of senators then emperors in the construction of monumental buildings, as well as a boom in private construction, coincided with considerable innovation: the use of all kinds of vaulted structures, with concrete taking the place of ashlar, the mass production of facings, and the organisation of work gangs. The intensity of work seems to have led to a standardisation in building procedures that even affected humble private buildings. Many of these innovations spread to provincial cities, which also enjoyed a boom in monumental building, supported by local competition for public office.

In Late Antiquity, some innovation continued in the sphere of civil monumental building associated with the imperial court: structures from the Baths of Diocletian or the Basilica of Maxentius to the building of Hagia Sophia never stopped seeking to be more ambitious in their vaulting, whilst the basilica at Trier impresses with the optical illusion employed in its apse windows.[28] As will be explored shortly, these high standards were not typical of monumental construction in most provincial cities, with the exception of some churches, or the houses of the very rich. In 6th c. Constantinople we have again named architects working on imperial monuments, who were well-known, wrote treatises, and carried out experiments, such as the first daring dome of Hagia Sophia, or the earthquake machine of Isidore. The pressure for innovation was perhaps not as great here as in military building, but the demand for political prestige still encouraged the construction of buildings that were awe-inspiring: contemporary sources exult over the quasi-miraculous appearance of the Aqueduct of Valens, and the Great Nymphaeum in the centre of the waterless city of Constantinople, in the same manner as did Justinian over the completion of Hagia Sophia.[29]

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[27] Joh. Eph. *HE* 6.24.

[28] Basilica of Maxentius: Giavarini (2005). Basilica of Trier: Zahn (1991). There is no study on the Baths of Diocletian.

In terms of craft production, changes seem to be largely confined to applications of materials to decorate portable art and monumental buildings. Innovation is perhaps most noted in the production of glass, which in the Near East at least seems a lot more common in Late Antiquity than it was earlier, both in terms of vessels and window glass.[30] The period is known for the production of gold-glass, and the virtuoso carving of cage cups.[31] Only a few of these technologies were new in themselves, but all certainly seem to have become more common, and reached a high-point of refinement. Artisans working with these techniques produced some masterpieces that stand comparison with the art of any period. Perhaps the diffusion and elaboration of glass production was incidental to, rather than intrinsically connected with function: the goal of glass vessels on a rich table or glass windows in a church was to impress the visitor, in the context of social or institutional competition. In such a context, displays of coded cultural knowledge in decorative schemes might be as important, or more important, than technical innovation. Here technological change was perhaps only a cultural accident, encouraged by the desires of the wealthy, who now preferred art in rare material or noteworthy for its intrinsically difficult production techniques, rather than previously popular 'illusionistic' artwork.[32] Of course, such changes in taste cannot have provided a very strong impetus for directional change, being inherently unstable and subject to cultural rather than economic or political pressures.

In contrast to craft production, agriculture saw a considerable number of technological changes that seem to relate to the desire to increase productivity. Scholars have pointed to the invention of the vertical coulter for the plough and the scythe, as well as to the increased diffusion of harvesting equipment and of the use of metal for ploughs.[33] M. Decker notes that the Saqiya irrigation device became much more widely diffused in this period; now it was found not just in Egypt but also in the Near East, just as Qanat systems (underground tunnels cut into aquifers) and the screw press became more popular in the latter region.[34]

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[29] Aqueduct and nymphaeum: Socrates *HE* 4.8 (presented as an oracle), see also Crow in this volume (270) on Them. *Or.* 13. Hagia Sophia: Procop. *de aed.* 1.1 (overall description) 1.1.33–35 (first dome); Anon. *Descr. S. Soph.* 27 ("Solomon I have surpassed you").

[30] Vessels: Jennings *et al.* (2006) 83. Window glass: O'Hea in this volume (233–48).

[31] Von Saldern (2004) 386–99, 467–74.

[32] Move away from illusionistic artwork: I thank Ellen Swift for this point.

None of these agricultural innovations can be readily connected to the intervention of the State. Admitedly, both Qanat systems and other irrigation devices often require some sort of collective management: thus it might be appropriate to see these changes as the result of estate owners making capital investments in technology, as they had in, for example, Early Imperial Tunisia, when pressing installations of three or more oil-presses were commonly constructed.[35] However, in this volume, T. Lewit sees a possible correlation between the adoption of screw-presses, and both owner-occupier landlords and peasant cultivators, whereas the great estates of Tunisia and Tripolitania estates did not embrace this change.

It is worth remembering that the Roman Mediterranean witnessed a society where agricultural produce (even beans) was sold in urban markets for cash, and where mass-produced Roman material culture bought from such earnings reached the humblest of rural sites.[36] In such a market system it may be that peasants had as much to gain from increased productivity as did major land-owners. The professionally-built stone houses of northern Syria suggest that some peasants even sought to engage in conspicuous consumption of purchased services.[37] A desire to increase production for sale would seem to provide the best context for the spread and development of many of the minor agricultural technologies in Late Antiquity.

In a similar vein, several innovations have been identified in the sphere of maritime technology. The late antique period saw the widespread adoption of lateen sails, which permitted ships to "tack" into the wind.[38] The 5th–6th c. saw the gradual replacement of tenon-built hulls with frame-first ship construction, whilst tar replaced lead as a protective cover for ships' hulls. These last two innovations, of which S. Kingsley places the epicentre in Palestine, represent cost-saving measures, allowing smaller craft to be built more cheaply and quickly.[39] Their regional context matches well with the continuing development of interregional trade from Syria-Palestine with adjacent regions. These changes coincide geographically with no known government imperative, like, for example, the *annona*. Here again, market pressures may be the cause of technological change, rather than the role of the State or the Church. Such an explanation, thought anachronistic a few decades ago, now seems highly plausible in the context of our current views of the late antique economy, which now take archaeology into consideration.[40]

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[33] See for example Jones (1981) and Randsborg (1991) 62.

[34] For Qanat systems see chapter in Decker (forthcoming).

[35] Hitchner (1990). A point made by Mattingly (1988).

[36] The sale of low-value agricultural produce by peasants for cash in the Roman Empire was noted by Millar (1981) 73, based on Apuleius 9.32. For a late antique market stall price list, with foodstuffs including beans see Roueché (1989) no. 213.

[37] The houses are not only built to a high standard but also have building inscriptions: Tate (1992).

[38] Basch (1997).

Other areas of technological innovation are documented, but can make one feel a little uncomfortable. Yet, in order to fully appreciate the late antique technological effort we need to be sensitive to the priorities of late antique people themselves. Obviously, there was much attention paid to the instruction of the Christian flock. Sermons, hymns and liturgy form part of a raft of techniques adapted to facilitate not only the diffusion of doctrine (through the use of simpler language) but also to coordinate believers into a coherent unit—or "crowd-control" as some have called it.[41] Ascetic works designed to regulate lifestyle, such as the Spiritual Ladder of John Climacus, can sometimes seem not far from modern self-improvement books.

It may seem rather odd to invoke organised religion as a force for technological change. Nevertheless, its influence should not be underestimated. M. O'Hea suggests (245–56) that the critical influence on the diffusion of window glass might have been in its use in churches as part of the paraphernalia of monumental art, designed to produce a sense of difference and wonder in the visitor. It may well be that the structures of the Church were as important in encouraging invention and diffusion as those of the State in this period, as they were later. For the Medieval period some scholars have considered monasteries to be equivalent to Roman forts as technological show cases, perhaps being responsible for the spread of water-mills to Ireland and other innovations.[42] This might have been the case earlier, especially as many late antique monasteries were securely installed as functioning rural estate centres by the 5th c.[43]

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[39] Kingsley (forthcoming).

[40] Papers in Kingsley and Decker (2001), especially 11–13, and 167–72.

[41] Auerbach (1965); Lim (1995).

[42] Greene (1994).

Stagnation

The technological profile of Late Antiquity is not entirely positive. It is noticeable that in many parts of the Roman Empire the 4th–6th c. saw the continued but faltering use of existing technology, through the perpetuation of old solutions, as seen in the low-level maintenance of Early Imperial buildings. This is often visible in Mediterranean cities, even before the 'urban decay' of the 6th–7th c., in the technology of baths, streets and other structures. In the municipal architecture of many cities, little changed. New building work, usually confined to repair, often looks like the patching up of old investment. As R. Santangeli Valenzani observes (443–45), 5th c. Rome saw a culture of repair and small-scale private building drawing on the late imperial tradition but associated with a qualitative deterioration in skill. Some late antique crafts give one the same impression: for example, the selective re-carving of sculpture on the friezes re-used in the Arch of Constantine.[44] One can have the feeling that artists were at best clinging onto ancient skills rather than developing new ones. This might reasonably be classed as technological 'stagnation'.

Explaining this development is not easy. Universal judgements about the loss of technical ability in Late Antiquity do not really suit the prosperous centuries before the Early Medieval transition. It has never been easy to defend ideas of 'decline' in one area of late antique art, in the presence of artistic brilliance in other sectors: such as in glass, silver plate or mosaic production. In some cases, one must entertain changes of taste. For example, radical changes in coin design between A.D. 288 and 298 (whereby representations of emperors lose their individuality), are so sudden that they must be the result of conscious choice rather than any decline in skill: they occur well within the professional life of one die-cutter.[45] Thus 'stagnation' in individual technologies can mask cultural changes: some technologies were perhaps less relevant than they were earlier, whilst others came to the fore. Such explanations may seem like special pleading, but it is worth remembering that from the mid-18th to mid-20th c. scholars often maintained that the Early Imperial period saw a less glorious level of human achievement than Greece—especially in matters of art and craft production—a judgement based on rigid criteria of academic analysis and on ignorance of the context of production. A similar revision of opinion about late antique 'stagnation' is possible when one considers the artistic output of the late antique world as a whole.

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[43] Brenk (2004).

[44] Ward-Perkins (1999) 227–33.

[45] Reece (2006) 126.

Cultural relativism works less well in explaining changes of building techniques: one can try to be culturally indifferent to an irregular wall composed of mixed, poorly sorted material, but such a wall will simply not be as strong as one that has been measured, properly levelled and built from well-chosen material. Yet it is important to note that poor building work often co-exists with contemporary construction of a very high standard on the same site. At Sagalassos in Pisidia, for example, the late antique civic building work is noticeably less-well constructed than 4th–6th c. additions to a large private domus, which has precisely measured room dimensions and tile masonry facing that make it look late 19th c. in date. The major churches of the city are also well built, using well-sorted spolia. In contrast, the late antique civic building work gives the impression of being planned and executed by vernacular builders, not professional architects: spolia is used in mixed, non-matching fashion and rubble walls are often employed.[46] Thus, in the case of Church E1, a spolia wall has been numbered, disassembled and rebuilt, very carefully. But in the repair of the city's nymphaeum, the same care is not evident: the blocks of the sculpted facade were taken down without any numbering, and were then put back up in an incorrect order. This sloppy method is also visible in repairs to the tetrapylon at Aphrodisias.[47]

These differences in architectural ability would seem best explained by finance: on a large scale, the difference between the quality of secular buildings, in imperial capitals and elsewhere, and those erected and repaired by city councils is very noticeable. The civic revenues of the later empire were just not enough to pay for the architects who were commanded by the taxation revenues of the emperor. If skill is any guide to training, the municipal authorities seem to have abandoned the professional architects who had decorated Early Imperial urban centres with monumental structures, and to have fallen back on local builders, who were happier building cottages and cow-sheds. On rich private buildings, the wealthy could employ professional architects: the adventurous architectural forms of the villas of Cercadilla or Montmaurin being obvious examples of a phenomenon that can be observed around the empire. The Church was also in this position: major churches were generally well-built. At the same time, at Sagalassos and elsewhere, there are plenty of small churches, perhaps paid for by minor patrons or local subscription, which were built with rubble walls similar to those found in poor private dwellings.

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[46] Site observations made as part of fieldwork at Sagalassos 2004–2006, not yet published.

[47] Basilica E1: Vandeput (1993) 93. Upper Agora Nymphaeum: poorly re-fit blocks are noted in conservation reports in Internal Reports from 2001 onwards. Aphrodisias: Smith (1996) 12–13.

Obviously, here the key to preserving skill was the availability of large-scale funding, to support building work above the level of cottages, sheds, barns and workshops. In the case of Early Imperial Rome, the patronage of public monuments was so great that it had a knock-on effect in all types of building: creating high minimum standards through technological advances.[48] In the absence of such patronage, it does not seem to have been possible to maintain complex building skills. Vernacular craftsmen, still surviving in each region, probably took up the extra work. If professionally-trained architects were not maintained at a high-level, their skill might disappear, and could not be reinvented by local impulse: this is obviously the case with the ill-fated Tiber Bridge built by Symmachus in Rome in the 380s: qualified men were not available and, despite the investment of much money, the structure collapsed. The consequences of skill loss can be seen in an account of the construction of a harbour mole at Akko in Palestine, in A.D. 866–83: no workman along the entire coast could undertake the work, until finally a retired architect was found in Jerusalem who remembered how to do it.[49]

Thus 'stagnation' (the localised loss of skill which coincides with positive developments within the same time period), can perhaps best be explained by changes in internal priorities within late antique society: some of these were merely changes in taste, but others are more profound, relating to differences in the way objects or buildings were paid for, and thus in the level of technical skill which might be supported. It is also important to situate any apparent 'stagnation' within a correct chronological perspective: the technological 'achievement' of Late Antiquity should be judged on the technology of the Roman Empire in the late 3rd c., not on the Principate. During the 3rd c. there was a collapse in demand for many skills: such as large scale relief sculpture and indeed statuary in many parts of the empire. Thus much statuary and large-scale relief carving, for example the victories on the Arch of Constantine, are poorly proportioned, as they represent a reinvention, whilst a surviving workshop at Aphrodisias had little problem combining the technical skill of earlier centuries with new canons of taste.[50]

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[48] Discussed by Zanini (383 n.13) and notably Wilson (2006).

[49] Rome: Symmachus *Ep.* 4.70; 4.76; *Relat.* 25, 26; Akko: Muhammad Ibn Ahmad Muqaddasi *The Best Divisions for Knowledge of the Regions: A Translation of Ahsan Al-Taqasim Fi Ma'Rifat Al-Aqalim*, ed. Collins (1994) 148.

Technological Change in the Early Medieval Transition

Recession

Despite much evidence for continuity and innovation in the 4th–6th c., one has to admit to a definite technological recession, at different times in different places, between the 5th and 7th c. A.D. As a result of these changes, complex technologies associated with Roman daily life became rarer or disappeared entirely from many regions. This once baffled progressive scholars of technology. Did it happen because incoming people were 'ethnically inferior' or 'forgetful', or was it the result of 'religion'? It is important to note that some explanations of this nature, popular during the 19th and 20th c., have until recently been taken quite seriously in academic circles: some historians of technology have attributed the emergence of western scientific progress to European religious and secular philosophy and regard China and other world civilizations as being intellectually handicapped by creeds which encouraged fatalism.[51] Faced with the archaeological record of Late Antiquity, we can quite quickly say that there is no chronological or geographical correlation between the adoption of Christianity or Islam and technological simplification, nor between technological simplification and political disintegration, for that matter.

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[50] Ward-Perkins (1999) 227–33; on survival of skill at Aphrodisias: see e.g. Smith (1999) 158–60.

[51] This view is present in part in White (1980) 249–51, and to a lesser extent still in Mokyr (1990) 201–202, where Medieval Christianity is seen as having a key role in technological development.

Yet, many Roman craft industries did disappear or recede in the Early Medieval transition—such as the mass-production of finewares. Simpler technological solutions took their place and centuries passed before older techniques were reintroduced from outside or readopted from somewhere within a neglected part of their technological repertoire. Most of this change was internal, rather than being the result of the practices of incomers. This is clear when styles continue but technologies change, as in the case of the Romanian pottery discussed by Arthur. Sometimes there was simply a reduction in the diffusion of a given technology—which became less prominent, though it did not disappear. The sub-Roman farm at Poundbury, near Dorchester, in south-west England, illustrates this point. Here Romano-British technologies—such as the so-called 'corn-dryer'—are present in scaled-down forms. Despite much change in the post-Roman landscape, earlier technologies had receded but had not become extinct, nor had they been replaced by those of incomers.[52]

When such changes are very great and involve everyday technologies of agriculture and craft production, the best correlate to explain this kind of technological recession, in the West and later the East, seems to be the deterioration and collapse of Roman economic structures: the taxation cycle, along with regional and long-distance trade, which supported great agricultural and artisanal production during Late Antiquity. Cultural choice does not work well as an explanation for this phenomenon, as technological recession also affected regions such as the Aegean Islands and Western Asia Minor, which did not alter their religion, or political and cultural allegiances. The decline of slavery, often considered a significant support of Roman technology, cannot be invoked either: these changes were widespread, affecting life on great estates as much as in tenant villages: the chronology of change correlates best with dislocation caused by prolonged warfare rather than any changes in social status.

Technological Survival

Amidst the gloom of post-Roman western technological collapse—of fineware, of new primary glass production, of masonry building and of some agricultural technologies—one cannot help but notice obviously unrepresentative examples of technological survival. Amongst these are some large scale building works: at Constantinople a new dome was provided for Hagia Irene in the mid-8th c., whilst at Rome the roofing of St Peter's basilica was repeatedly replaced / repaired during the 7th and 8th c. The maintenance of city walls and aqueducts in Early Medieval Rome is also deeply impressive.[53] At Aachen, the palatine chapel and imperial audience hall stand out as the skyscrapers of the 8th c. More widespread is the survival of high quality metalwork including pattern-welded swords and late antique arms and armour such as the Spangenhelm; manuscript illumination, glass and ivory working are also obvious examples. Many of these items occupy pride of place on the front covers of books on the Early Medieval world: presenting a greatly distorted image of the ruined society from which they were derived. Of course, the technology of nearly all this material is essentially late antique, although it was present in much smaller quantities than two or three centuries earlier.[54]

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[52] Green (1988).

So why might certain technologies have survived, largely unchanged, whilst others did not? The best explanation seems to lie in the selective survival of demand. It is very noticeable that it is elite crafts which survive—the swords used by leading warriors, or the trinkets that decorated a lord's table, a point which is well-illustrated in the social stratification of finds in Early Medieval cemeteries. The elite can concentrate resources even in hard times to pay for craftsmen—thus workshop traditions focusing on prestige goods survived in many places, whilst those which produced for a wider clientelle were wiped out.[55] Even the survival of brick production in Northern Italy, after the 6th c., was a result of the organisation of manufacture for monumental building projects, rather than of the survival of a broad-based commercial market.[56] In contrast, the level of technological survival seen in the Early Islamic Near East, in craft production and agricultural technology, seems to represent the opposite situation, where the persistence of economic structures ensured continuity in workshop skill.

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[53] Hagia Irene: Peschlow (1977). Roof of St Peter's: see references assembled in Ward-Perkins (1984) 62; On Rome in general see: Coates-Stephens (1998). U. Peschlow (1977) *Die Irenenkirche in Istanbul. Untersuchungen zur Architektur* (Istanbuler Mitteilungen, Beiheft 18) (Tübingen 1977).

[54] Book covers: e.g. Webster and Brown (1997); Diebold (2000). On the issue of impoverishment and technological simplification see Ward-Perkins (2005) 87–120.

[55] The survival of the art of the Church relates to the simple survival of concentrated demand. But, for northern Europe, the survival of some metalwork etc. vs. stone building is perhaps also associated with a reassertion of the value of portable art, well-suited to peripatetic elite lifestyles, as it was in the Late Iron Age. Social change also meant that weapons and dress items were more critically important in elite display than earlier.

The survival of engineering technologies in the Medieval Byzantine Empire, as described by M. Lewis (367–78), would seem to be dependent on somewhat different circumstances. These circumstances were perhaps the survival of imperial patronage, the military necessity of withstanding the efforts of very powerful neighbours, and the cultural habit of copying a wide variety of ancient manuscripts. It would be interesting to know what percentage of late antique civil engineering techniques survived in widespread use outside of these special contexts. Until the archaeology of Middle Byzantium is better advanced it seems impossible to respond to this question. Nevertheless, the scale of technological survival within Byzantium marks it out as very different from its western neighbours.

"Simpler" Solutions

Lest technology appear to be just the history of one linear march, either forward or back, we should also consider the adoption of apparently simpler solutions to everyday problems, in the context of wider technological recession. In 5th c. Britain or the 7th c. Balkans there must have been many people who reacted to the loss of traded goods by looking for simpler alternatives. This might have taken the form of re-using objects for new purposes, as with the bases of Roman jugs which were sometimes used as Merovingian gaming counters. Alternative solutions included the repair and the conservation of house objects, for as long as possible. Unfortunately, repairs are fragile, and the conservation of valuable objects is difficult to trace, outside of contexts such as the Verona well hoards, or church treasuries.

We also have to envisage that post-Roman society could have responded to change by looking inwards, to expand the use of alternative solutions within its own existing technological repertoire: its "technology shelf". This might have involved switching from ceramics and metal items to those produced in wood or other perishable materials.

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[56] Gelichi S. and Novara P. (2000) edd. *I laterizi nell'alto medioevo italiano* (Ravenna 2000).

It might also involve using simple solutions more widely: thus we see an expansion in the use of *clibani* (simple ceramic hearth covers used as bread ovens) from the 5th–6th c., and especially later, in Italy and the Balkans, as described by P. Arthur (178); similarly, wooden buildings present in the Roman countryside might now take the place of masonry structures, as in Tuscany, as described by M. Valenti (459–70). Such changes might occur without the loss of much technical sophistication—solutions might already have existed within lower levels of the technological vocabulary of late antique society, making possible an expansion of existing simpler technologies to fill the gap created by the demise of high technologies. However, it must be admitted that the archaeological record for regions such as the Danube and Britain suggests the opposite—that there was a collapse of technology at the end of Roman occupation, that left users with few technical alternatives in many sectors. The supremacy of Roman technology had once caused some Iron Age solutions to be discarded. Now the end of the Roman economy left people in these regions without either.[57]

Innovations under Pressure

The reaction of a population to difficult circumstances might in some instances take the form of innovation. One should not forget that there were some innovations made in the darkest parts of the Dark Ages, probably precisely because of the pressures which this period brought. Greek Fire, developed by Constantinople to counter Arab naval power in the later 7th c., is the most obvious example.[58] Here the crisis of the siege of Constantinople in A.D. 674 provided the necessary impetus to concentrate minds, as had the siege of Syracuse in 212 B.C., in which the inventions of Archimedes played an important role. Aside from invention under pressure, there will of course always be some diffusion of technologies either from outside, or from within. Thus, lead-glazed pottery, invented in Asia Minor in the 1st c. B.C., did not become widely diffused until the Early Medieval period, perhaps caused by the disinterest of consumers, or restricted contexts of production.[59] There was probably also still some innovation as a result of an ever-present level of invention that is a constituent part of crafts which depend on trial and error: thus it has been noted that Early Medieval niello adheres rather better as an inlay in silver, than its Roman predecessor.[60] However, inevitably, the extent of the application of discoveries of the era was probably far more limited than it had been earlier, when faced with the straitened circumstances of the Early Medieval period.

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[57] For a review of the post-Roman situation in Britain, see Ward-Perkins (2001) 117–120. Archaeology on the Danube has not really even begun to detect occupation of 7th c. date.

[58] See Haldon (2006) for a review of the state of research into Greek Fire.

[59] See Arthur in this volume (176–78) and also Greene (2007).

Cultural Replacement

Whilst many of the technological changes associated with the Early Medieval transition favour internal evolution, the potential for cultural replacement of technology should not be underestimated. Some technologies were perhaps so closely associated with the specific cultural practices that replacement of one with another is to be expected on the arrival of an incoming group. This could be true of alphabets: thus, the presence of Ogham inscriptions in Wales in the 5th–6th c. is connected to the presence of settlers from Ireland.[61] The appearance of near-eastern agricultural technologies in Early Medieval Spain, also seems reasonably connected to the arrival of the Arabs.[62] Such scenarios of replacement could be encouraged by conservative craft traditions and domestic habits, passed from one generation to another, which might fail to absorb innovations. Nevertheless, it is increasingly true that much that was once considered 'Germanic' in the Early Medieval material assemblage finds its origin in Late Roman practices, and this extends to technology as much as to form and decoration. Thus, it is important not to overuse 'replacement' as an explanation for technological change in this period.

CONCLUSION

The technological changes of the period A.D. 300–650 are clearly complex, and do not fit within a single model of 'decline'. The technology of the late antique Mediterranean, from the 4th to 6th centuries A.D., was still part of the Hellenistic and Roman technological tradition, which saw much innovation, through both invention and diffusion from elsewhere. The Roman State, and probably the Church, played an important role in preserving complex technologies, and in encouraging new solutions. The economy, notably the pressures of production for sale, played a significant though less obvious role, supporting innovations of greater daily application. 'Stagnation' was present, but can be related to internal changes in society (political and cultural), and co-existed with continuity and invention in different professions. However, some of the differences between early imperial and late antique technologies (such as those in large scale-relief carving, or in metal extraction) can be related to dislocations of the 3rd c., and so tell us little about the conditions of the 4th–6th c.

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[60] La Niece (1983).

[61] Sims-Williams (2002).

[62] Glick (2005) 42–112, 247–94.

The Early Medieval transition provides a chance to gain an even more fascinating insight into the nature of technological change, in a society "after complexity"—one that has entered an economically depressed period. In such cases, the technological profile of a culture is not same as for a society pre-complexity—there are pockets of conserved brilliance amidst evidence of simplification, all of which demands specific contextual explanation. Yet, just as in Late Antiquity, wider general pressures can be identified that influenced technological change, such as the collapse of market systems during prolonged military conflict. Nevertheless, change even in this period, is not all unidirectional: extreme pressures can spark innovation, as well as the abandonment of high technology.

Despite these remarks, the correlation of specific technological changes with contemporary contextual factors is largely based on guesswork. Whilst some links may be obvious, others will probably be eternally open to debate. Most advances in explanation are likely to come from the empirical observation of the nature of technology within late antique and Early Medieval society, and its closer correlation with factors governing the means of production, as they are situated regionally, socially and politically. Finally, the contribution of the Islamic world as an 'external reservoir' of antique technological solutions in the Early Middle Ages also needs to be quantified. Some Hellenistic technologies are present here that have not yet been detected in the late antique world. Were they the heritage of Late Antiquity? or were they re-discovered from studying surviving ancient texts? The resolution of such questions lies in future work.

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THE TRANSMISSION OF CRAFT TECHNIQUES ACCORDING TO THE PRINCIPLES OF MATERIAL CULTURE: CONTINUITY AND RUPTURE

Tiziano Mannoni

Abstract

This article investigates the cultural mechanisms through which craft techniques were transmitted or lost during the transition from Late Antiquity to the Early Middle Ages. It considers specific scenarios, many of direct relevance to the period, which could have contributed to technical change. These scenarios are illustrated with relevant examples from the period. Northern Italy is the main focus of inquiry, although the conclusions drawn affect other regions. Particular interest is taken in the adoption of steatite vessels for cooking.

Introduction

Ars for the Romans, or *teknè* for the Greeks, either meant a manufactured item, the knowledge to produce it, or the guild that acknowledged, approved and controlled the work of their own *artifices*. Once the last *artifex* of a guild died without an apprentice, the accumulated knowledge of their craft ceased and disappeared. In this article, 'artisanal technique' is defined either as a choice of tools or utensils, the way in which they were used in manufacture, depending on the material that was used and the shape that was to be obtained, or the entire process, or succession of necessary operations, undertaken to achieve a product. It is not intended to encompass intellectual products, or to be a synonym of the production process. Rather, 'artisanal techniques' will be considered to be the active tools of material culture. 'Material culture' will be taken to mean the cultural knowledge used to produce objects in order to solve existing problems, or at least to keep things as they are. This knowledge is generally obtained by trial and error, and passed

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on within communities of 'master craftsmen' and apprentices.[1] It is limited by the environmental functions for which a product is intended and the characteristics of the raw materials used in its creation, which depend, in turn, on the laws of nature, which do not change through time and space, and which, in material culture, always influence the 'rules' of every form of craft.[2]

It is clear that when investigating the continuity and discontinuity of techniques in any time period, it is necessary to examine the archaeological evidence for a specific technological change. This is a first, necessary, and very useful step, so long as it is carried out in an objective way, if possible with the help of the scientific data supplied by archaeometry. Interpretative discussions are then required to place these objective observations in a historical context. However, where an analysis of production is concerned, this approach is inadequate without a consideration of the laws of material culture. Such a discussion must examine how societies obtain and lose empirical knowledge across a number of generations, and thus raises a number of questions. How much of such knowledge can be discovered through experiment in the first place? Can it be deduced by an artisan from an examination of finished, inherited products, without an apprenticeship system? What other human factors, rational or irrational, might interfere with the transfer of technical knowledge?[3] Here, I will propose a list of hypothetical scenarios in which technical change might occur, bearing in mind determining factors relating to the criteria set out above. This is obviously not intended to be an exhaustive explanation, but simply a guide to the discussion. Indeed, such a complex problem could not be solved by my argument alone.

Workshops as Contexts of Technical Knowledge

Production is always subordinate to the desires and critical control of the consumer, to whom it is connected through a system for the distribution and circulation of products. Consumers test the functionality and durability of products in a practical way. It is also important to take into account their culturally determined levels of satisfaction, whether aesthetic or symbolic, and responses to changing fashions. However, there are many factors that are internal to workshop culture which encourage the continuity of manufacturing techniques over a long period of time, in an empirical world.

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[1] Popper and Eccles (1981); Mannoni and Giannichedda (1996).

[2] Rossi (1975). On this subject, see the 'experiments of light' and the 'experiments of fruit' of Sir Francis Bacon.

[3] Mannoni and Giannichedda (1996); Cavalli Sforza (2004).

Production itself was governed by two tendencies in medieval Europe, one conservative and one progressive, which can be considered two extremes within the same system. Empirical craftsmen did not know the origins of the conventions, adhered to by their art, which provided the best results; therefore, they did not tend to take risks, and stayed faithful to the established ways of doing things, as was required by the guilds to which they tended to belong. Such a conservative tendency can lead to homogeneity in production over long periods, which has greatly assisted the typological surveys of archaeologists. Nevertheless, it is always counterbalanced to some degree by a progressive tendency.

Those artisans who have little fear of making mistakes have always produced a few small technical variations, stable and personalised, without straying from the official regulations. When the importance of an aesthetic element increases in a product as a result of such variations (artistic techniques), it can come to characterise an ethnic group,[4] an industrial unit, or even a single artist. These stylistic differences are limited, but very useful when they are skilfully applied to identical products that are to be used together (tiles, etc.); ultimately they make the ensemble appear considerably more beautiful than if it had been composed of identical elements. However, such variations never involve thorough and substantial changes to basic production techniques.

In every craft, as in every field of knowledge, there are always some workers who, because of their talent for the job, learn more quickly than others, and who always want to know more than is considered normal according to contemporary practice. Such craftsmen might rise quickly through the career grades of their craft, to become what, since the Renaissance, has often been called an ‘artist’. For example, the following career grades were established among Italian stonemasons: stone-squarer (*squadratore*), moulder (*modanatore*), decorator (*ornatista*) and sculptor (*scultore*). ‘Restless’ artisans, who might rise rapidly through these grades, were pre-disposed to quickly adopt innovative practices that manifested themselves in either the material culture or economy of contemporary society; these innovations resulted in changes to both products and to techniques. Such people were, by their very nature, interested in experiments and, once they had achieved the results they desired, almost always opened the way for new craft regulations, which were then generally taught and learned.[5]

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[4] Leroy-Gourhan (1964).

It is difficult to establish, in these phases of technical change, how much depended on material culture of artisans, or experiments with results, as Bacon would say, and how much depended on existential culture, or irrational explanations given by empirical craftsmen, for the causes of results, as Galileo would say.[6] It would surely be misleading to think that men without scientific knowledge would not be sufficiently curious to know the reasons behind what they were doing. Vitruvius sought to use the natural philosophy of the Greeks—that of the four elements. Others certainly resorted to religious or magical explanations, whilst some believed that it was the result of their personal intuition. Nevertheless, in all probability, these beliefs did not actually modify basic craft or production techniques, just as the scientific knowledge of a modern artisan does not affect his craft techniques, even if he entertains himself by explaining his every action according to the laws of physics. Rather craft techniques were most probably governed by workshop tradition and trial and error. The influence of existential culture should be sought principally in the aesthetic aspects of products, in their symbolic value and in the consideration they show for taste and fashion.[7]

Scenarios of Technical Change

There are many factors that can influence the continuity and discontinuity of artisanal techniques, certainly many more than those outlined above. However, no linear formulae exist that can be used to study their interaction objectively;[8] therefore, this complex subject can be approached more logically through case-studies involving different factors, which will be presented in the text which follows. Not all of the examples given are valid for every region of the empire: the cases are mainly Italian, more particularly from northern Italy, and to do more would require lengthier discussion than is possible here. Indeed, the examples given are not intended to represent a paradigm, but simply allow us to go beyond a completely theoretical discourse.

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[5] Mannoni (2003a).

[6] Giusti (1990).

[7] Mannoni (2002a); (2002b) and (2004b).

[8] Bechmann (1990).

1. *The Product is No Longer Useful*

Sometimes a practical problem, which an object was created to solve, disappears, or, as is almost always the case, is transformed into a new problem. Often, when the demand for a product ceases, artisans will try to use the same working organisation and techniques to produce objects that are destined for different purposes. However, when there are no other products that can be manufactured in the same way, certain techniques might disappear, as the transfer of practical expertise through production is interrupted. For example, in Late Antiquity, temples, theatres and amphitheatres eventually ceased to be used and, therefore, were no longer built. As a result, it is possible that certain construction techniques were completely lost in the West. One example is the structural system used in amphitheatres, based on a succession of barrel vaults and arches that eliminated all lateral thrust.[9] The end of tableware production is another relevant case. This seems to have been caused by an enormous decrease in demand, rather than by any difficulty in production. Indeed, it is perhaps no coincidence that this development coincided with a crisis in food supplies, and the abandonment and ruralisation of many cities. Nonetheless, the end of tableware production, which had been characterised by various distinctive functional shapes, brought with it the complete disappearance of the technique of coating crockery with genuine sintered varnish.

2. *The Product is Replaced by Another Product*

The essential problem which any act of production seeks solve, discussed in the preceding paragraph, can still exist, but can sometimes be solved by another product that is deemed to be better-suited. In the case of the table-services mentioned above, for example, it is thought that various shapes were substituted by vessels made of polished wood, since such products are well-documented by written and iconographic sources, both before and after A.D. 1000.[10] Nevertheless, we lack solid proof that the start of this production coincided with the end of the production of Late Roman ceramics; a lack of proof that could, however, be due to the rare preservation of wood.

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[9] Ward-Perkins (1974).

An interesting example, which contradicts this trend, is provided by cooking vessels. The vitreous coating of ceramic recipients began in some eastern industrial units during the first centuries of the Empire, with the aim of imitating bronze vessels that were decorated with *repoussé*. During the following centuries, it appears that the waterproof function of this coating was also noticed, and that glazes were progressively applied to vessels for liquids, either for the table or for the kitchen. This technique, which experienced periods of greater of lesser favour, only recently came to an end in the Mediterranean region.

Despite the end of the empire, the regional production of traditional earthenware pots continued, with a possible improvement represented by glazed examples. The intensive trading of these products began in the regions north and south of the Alps, where the raw material for steatite fire-resistant dishes can be found. These vessels continued to be used throughout the Middle Ages. They came into use despite the fact that they were heavy to transport, and despite the functional and political crises afflicting the relevant communication routes across the Alps. For instance, they are the only products that archaeological evidence has identified as having been traded abundantly between the Lombard and Byzantine regions of Italy. Ethno-archaeological research, linked to archaeometry, has shown the remarkable ability of steatite to cook food thoroughly without burning its surface, due to its very low thermal conductivity.[11]

3. *New Uses for Old Products*

Sometimes a product can also prove to be useful for a new purpose. Steatite again provides a useful example, as its use has changed more than once over time. When it was first used in the Alps, in the first centuries of the empire, it was employed as a fireproof material in moulds for casting melted metal and for oil lamps. Later on, however, it came to be appreciated primarily for its low thermal conductivity and used to make cooking vessels. Towards the end of the empire, though, with the spread of glassmaking in the West, even if only on a small-scale, the fireproof ability of steatite was re-discovered, and vessels that were destined to be used as melting pots were often made out of it. In these cases, apart from some small adaptations, it is nevertheless obvious that we are not dealing with significant changes in technical expertise or production techniques.

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[10] Lombard (1972); Mannoni and Mannoni (1975).

[11] Giannichedda and Mannoni (2002).

4. *Demand for a Specific Product Disappears, Causing Production to Cease or Evolve*

In the Early Medieval transition, the number of craft techniques which disappeared was greater than those which were newly introduced. But of those that disappeared, perhaps the only technique that was not re-introduced at a later date from elsewhere was that used to produce sintered varnish for tableware: this technique has only recently been re-discovered empirically by forgers. Other techniques that ceased to be used in the West during Antiquity, such as the large-scale exploitation of marble quarries, or the use of *opus quadratum* in construction, were resumed later in the Middle Ages, when they were employed once more by workmen from the Middle East, a region in which such activities had never ceased. This rupture in so many techniques obviously reflected substantial changes in demand consequent on the disruption of the Roman economy.

In this situation, it is, however, important to note that new products appeared for which no new techniques seem to have been necessary. This was true of wooden tableware, mentioned above. In this case, new products could be developed without any technical innovation, the turning of wood being a very ancient tradition. Similarly, the production of ceramic *testelli* (small, shallow plates) for the baking of small *focaccia* (typical of the northern Apennines) began in the period of urban abandonment during the Early Middle Ages, even though the techniques according to which they were manufactured were perfectly consistent with existing ceramic craftsmanship, albeit somewhat simplified. Furthermore, although *testelli* were made using a rare clay with low thermal conductivity[12] (produced by being superheated before being used for cooking), this does not constitute a real innovation, given that these clays were already being used for pots in the Roman period and much earlier. Neither can one talk of an innovation in cooking techniques, because bread and *focaccia* were already being baked in embers in Antiquity.

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[12] Clay from gabbro and from basic volcanic rock, or the addition of ground lime, if these were not available.

It can be concluded that, despite great changes and the emergence of new socio-economic conditions, certain potters took the basic knowledge that they had acquired in large industrial units producing 'common ware', and organised a new, simplified production technique that was easier to learn. This was to constitute one of the many artisanal customs of medieval rural society, which conserved and transmitted the fundamental rules of ancient ceramic craftwork, providing objects that, although trivial-looking, functioned well, and were of much use to that particular culture.[13]

5. *New Experiments are Undertaken*

Almost every technological change, except for a complete cessation in a cycle of production, requires some experimentation. This might include the situations envisaged by scenario 1, where an attempt was made to avoid the cessation of manufacturing activity, and produce similar objects with a different function. It would be worth studying, for example, if and how the sculptors of bronze statues became bell casters in the Early Middle Ages, as the same technique was used in both cases.[14] In situations envisaged by scenario 2, experiments might be undertaken in order to refine either a new product or a 'fallback product' by applying unusual techniques. Thus, the introduction of the wood-turning lathe to shape steatite receptacles not only quickened the process, but also permitted the production of thinner and more regular sides, after appropriate measures had been taken. But mastering the techniques to make a new product a success was no easy task. If innovation was the result of local craftsmanship, a long period of experimentation would be necessary, whilst if it was stimulated by customs imported from another area, it may have required the search for suitable local materials. At the same time, it might have been necessary to have local craftsmen acquire experience in a different region, or have master craftsmen move into a region to transform craft techniques in this way: a medieval example concerns the master-builders of the Lombard Plain who, wherever they went to work, were always looking for dolomite quarries that produced very resistant magnesic lime.

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[13] Mannoni (1965).

[14] Giannichedda and Mannoni (2002).

6. *Irrational Ideas Inspire Change*

One should not think that irrational explanations for the technical qualities of a product could not play an important part in its development. Here, I am not primarily concerned with irrationality in the design of a product by a craftsman, but rather the ideas that accompanied an object and influenced consumers, who ultimately decided which objects were to be produced. A relevant example can be imagined in medicine. If, in pre-modern times, it had been discovered through experiment that the fungus Ergot helped reduce epileptic fits, the successful remedy might well have been attributed to an act of 'white' magic because Ergot was considered to be a fruit that was at odds with the rules of nature. It might have been argued that it was effective because 'evil attracts evil'. Therefore, it is possible that an apothecary might have tried to increase the effect of the medicine by combining it with other 'negative fruits', such as bats' livers. The latter technique could only have had a psychological effect, even though it is now known that Ergot does have an influence because it contains alkaloids that are the root cause of its positive effects.

In the absence of accurate literary sources, it is difficult to know, for example, whether steatite vessels were only in demand for their thermal characteristics. We know today that these depend on the minerals from which the vessels are composed (which could correspond with the passage by Pliny on the stones of Syphos and Como: *cavatur tornaturque in vasa vel coquendis cibis utilia vel ad esculentorum usus*…).[15] However, it is possible that in the Early Middle Ages, these vessels would have been valued for other qualities, such as a power to remedy the effects of poison. This explanation of their popularity is not entirely dissimilar from current marketing campaigns for steatite cooking plates, which focus on their ability to mitigate against the carcinogenic effects of burnt food.

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[15] Plin. *Nat. Hist.*, 36. 44.

7. *Despite the Closure of Industrial Units, Technical Ability is Retained, by Re-ordering Production*

So long as the urban system functioned, large-scale artisanal establishments producing goods for general consumption were concentrated on the periphery of the cities, and their products were distributed in all regions. In the countryside, industrial units were installed to provide items needed by specialised agricultural practices, and small workshops established that offered different services. Some minor centres acquired a predominantly artisanal character on account of their proximity to raw materials or important commercial routes. In such settlements, many masters of the same craft could work in the same centre, and live in the precincts of the corporation, where levels of specialisation probably varied to a greater extent.

Whoever came from a working community like this would have understood the basic techniques required to undertake a complete production cycle, which they had experienced during their apprenticeship and after. They would be sufficiently practised in these techniques to execute them to the standard level, and would have also acquired some knowledge of how they were carried out at higher levels, which involved more difficult or aesthetically-demanding operations. Thus, if it were asked of them, they would have been able to organise and conduct a complete production cycle for small quantities of a product, with clear, minimum standards for their operations.[16] Consequently, when such large production units closed, it might have been possible for some artisans to set up small-scale, cellular operations, which preserved these skills at a reduced level over a given territory. The occasional preservation of such specialised skills after Antiquity is noticeable in the repair of old objects. Repairs carried out by itinerant workmen serving a regional market can generally be distinguished from 'do-it-yourself' repairs, because of the differing quality of their execution.

8. *The Organisation of Production is Modified in Some Other Way*

The factors outlined above, probably correspond best to the principal changes that occurred in production at the end of Late Antiquity, and to the way in which they have been brought to light by archaeological research. These are changes that mainly concerned the organisation of production, rather than the techniques involved, which instead seem to have survived remarkably well. Such changes may have taken many forms other than those expressed above. To fully comprehend such changes, it is necessary to consider whether smiths, glassmakers or goldsmiths in late antique or Early Medieval villages were resident artisans, or transient, itinerant workers. The latter seems to have been common, judging by the prevailing scarcity of production waste, at least in northern Italy.[17] Furthermore, it is important to know which types of products, within a given craft, each artisan was able to produce. At the same time, one should not forget that some large industrial units producing a whole range of objects continued to exist throughout the Dark Ages, as has been demonstrated in the Crypta Balbi at Rome and at San Vincenzo al Volturno.

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[16] Mannoni and Giannichedda (1996).

9. *Adoption of Techniques from Other Manufacturing Trades or Other Cultures*

The horizontal lathe introduced in the Alps to produce steatite vessels is technically equal to the one used to turn wood, which is derived from 2nd millennium B.C. Egypt. However, some adaptations were needed in order to use hydraulic energy because of the much heavier weight of stone blocks, and also because of the method of attaching them to the lathe itself.

The way in which such techniques could be transferred from one craft to another is not unusual. Rather, it is common in the evolutionary phases of every production cycle. When artisans interested in innovations exploited social changes to improve production, they often drew the inspiration for their experimental research from practices that were already successfully used in other trades to resolve analogous problems. For example, ancient and medieval bronze sculptors frequently applied finishing and additions to cast works with utensils and techniques normally used by stonecutters and goldsmiths. Thus, investigations of Michelangelo's work still mistake the punctiform traces left by the use of the cutting chisel in his 'unfinished works' for the use of the drill, as scholars forget that having grown up in a family of stonecutters, Michelangelo was encouraged to use tools not used by sculptors.[18]

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[17] Mannoni and Cucchiara (2001).

When, in contrast, consumers and local producers favour products manufactured in other, distant cultures, workmen from the relevant regions are generally sent for. This trend has already been mentioned with respect to the re-opening of marble quarries and the re-introduction of *opus quadratum*. Savonese merchants did this in the 12th c. to produce the *graffita arcaica* ceramics in Liguria. In other cases, people tried to use local techniques and materials that they deemed suitable for the imitatation of the originals, although such attempts never came close to producing the results achieved by foreign artisans. Nevertheless, such attempts to imitate can be a technological stimulus in their own right. Chinese porcelain, for example, with its magnificent colours glittering on white surfaces, excited consumers and Middle-Eastern potters, and later western potters, for almost 1,000 years, until the beginning of the 18th c. At this point, the Europeans finally learnt how to produce such porcelain by using the same techniques. During the long period preceding this time, craftsmen had only been able to produce imitations of the white-finished vessels by different techniques. For instance, the vases were made with a siliceous body and coated with a thick glaze, or with a ceramic core coated with a white *ingobbio* or with a white stanniferous enamel, from which all the different qualities of majolica are derived.

10. *Changes in Artistic Techniques Related to Taste*

Changes in the taste or fashion of a group of consumers can be complex. Many non-linear and interactive factors can influence such developments. Indeed, at times, a factor of limited importance during an initial phase can determine the entire change. Generally, one's taste is related to one's appreciation of beauty and one's outlook on the quality of life. It can change radically along with works of art, the appeal of which is often determined by particular visions and beliefs about existence. The same has often been said about the evolution of late antique decorative techniques.

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[18] Giovannini (1998).

Thus, it would be misleading to think that the geometric irregularities and poor realism of the figures that adorn decorative objects produced in Late Antiquity are to be attributed to the lesser ability of itinerant or isolated artisans, or to the clear supremacy of barbarian artisans. The remains of a large workshop of a goldsmith in the Crypta Balbi show that objects fashionable in both the Byzantine and Lombard communities were in fact produced together. It is well known that, already in the Roman world, there was an artistic movement away from depictions of a naturalistic beauty to works portraying a more inward and symbolic form that was better adapted to new visions of human existence. This new art form resembles, at first glance, the approach to abstract and symbolic beauty often used by the artists of invading barbarian groups. However, this similarity is only superficial. The only common denominator is their detachment from classical realism.

Therefore, a fashion can come into existence to win the favour of new rulers, who can, in some cases, be equally pleased and influenced by the taste of their subjects, especially when they come to rule over more complex cultures than their own. Furthermore, merchants tend to favour exotic fashions with which they have connections, partly because of their own taste, but also because their merchandise is easier to distinguish and publicise when part of such a fashion. There are, of course, always formal and decorative changes that relate to an exotic influence. However, good manufacturers never apply these at the expense of a product's functionality. Nevertheless, such alterations often require specific artistic techniques, which can require changes to even basic production techniques.

11. *Subtle Changes in Overall Demand*

The quantity of objects that are produced in any one time or place obviously depends on the demand for them. This is dictated to varying degrees by more general factors, such as the extent of the region of commercial distribution, by communication routes and commercial organisation, by the purchasing power of a market, and by the quality of the product itself, as determined by consumers, from either an objective or subjective perspective. But demand also depends on the successful use of products, and therefore, on the relationship between materials and the techniques of production, and on the techniques according to which the product is used. For example, a myriad of different uses could, in turn, lead to changes in the demand for products made using different techniques.

It is difficult to establish how much of this summarised economic logic was active in a given historical period and, above all, to point out which of the several active elements had a greater importance than others. Nevertheless, we cannot resolve complex problems by ignoring them. Instead, it is much better to create theories, or even simple conjectures, and to keep these in mind during archaeological research, even before interpreting remains, rather than to assume that a much simpler ancient economic system existed, on the basis that it is not possible to precisely evaluate its principal elements. Indeed, it is even difficult to accurately assess the levels of demand and their interaction in the modern economy. However, this does not mean that they do not have important consequences for most people.

12. *Generalised Economic Collapse*

Economic history is not easy to reconstruct: substantial difficulties exist in reliably reconstructing the economic value of manufactured goods and the purchasing power of money, even with the indispensable help of written sources. But there seems no doubt that there was an economic crisis in the late antique period. From an archaeological viewpoint, the partial abandonment and the advanced ruralisation of many urban centres in northern Italy is obvious; it coincides with a progressive repopulation of mountainous areas, and with wooden houses built on terraces halfway up the hillside, a settlement pattern that sometimes coincides with the preceding model of the proto-historic population. In agriculture, some new production cycles were introduced: rye substituted barley as a cereal, which in the mountains is more productive than wheat; and the sweet chestnut began to be cultivated. It is, of course, possible that new growing techniques were introduced in these cases.

If one analyses the distribution of moveable goods in northern Italy, a tendency to an autarkic economy can be noted in new mountain settlements. In contrast, smaller centres on road axes seem to have exhibited few differences to the cities, because some traffic still passed through them. Such contrasts are visible on a large-scale. For example, according to the archaeological remains, during the Byzantine occupation of the *Maritima Italorum*, certain urban areas, such as the fortified settlements that controlled the mountain passes, imported large quantities of mass-produced goods from North Africa and the Middle East, with percentages ranging from 50 to 90 per cent in the archaeological record. Meanwhile, only small quantities of steatite vessels arrived from the Lombard area.

13. *Limited Availability of Raw Materials*

For products which required materials that were neither easily available, nor extremely rare—as in the case of *lapis lazuli* blue—the availability of the raw material could be a factor affecting the diffusion of techniques. The rarity of steatite has already been discussed. In Europe, it is found in only five valleys of the western Alps. In addition, because this material is very heavy, it has never been convenient to transport as raw material over great distances, and the workshops for turning vessels made out of it have always been close to the places of extraction. Nonetheless, the finished products were still traded. The technique was already focused on a regional market in the 3rd–4th centuries A.D. However, from the 5th c., it was the product itself, not the raw material or the technique, which spread throughout a vast area, as a result of its functional characteristics.[19]

Roman and post-medieval use of hydraulic mortar was also affected by local availability of raw material. This was indispensable for public works such as aqueducts, cisterns and harbours. Cocciopesto (*opus signinum*) was used in almost the entire ancient world, and also afterwards, perhaps because, in most places, it is easy to find earth to make terracotta. But the Romans had also inherited and developed the use of Pozzolana, which appeared in the volcanic Campano-Latial system: only in the valley of the Reno and in some Anatolian regions was a comparable volcanic material used. Consequently, there was a restricted distribution of hydraulic mortar, which despite being highly superior to other mortar mixes, was largely confined to the region.

14. *Limited Availability of Specialised Labour*

It is possible that other factors apart from product quality affected the transportation of raw materials. In late medieval and early modern Genoa, hydraulic mortar was produced using kaolin, which the Genoese extracted on the Anatolian shore of the Aegean Sea. It is obvious that bulky and heavy raw materials could be transported by water over a long distance if they were especially valued. However, it appears that the technique of fired kaolin used in Genoa was a Greco-Byzantine tradition that was introduced by experts of the same provenance, working in the port of Genoa in the 15th c.[20]

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[19] Mannoni (1986).

15. *Limited Availability of Unspecialised Labour*

It has long been suggested that a key aspect of the Early Medieval transition was the progressive diminution and disappearance of slavery, which constituted for many centuries a convenient manpower resource. Although difficult to prove, one might entertain the notion that this was associated with changes in the supply of labour. However, in technical terms, the replacement of human labour by animals did not require many significant changes in technique. However, the adoption of water-power did, and it is worth considering if the popularity of water mills for grinding flour had something to do with the disappearance of slave labour.

Prehistoric handmills required much hard labour and considerable man hours, their millstones needing to be manually rocked, with strong movements of squeezing and pulling, adapted to the basic elements of the task: the elimination and cutting of the hard hulls, and their transformation into flour. Around the 5th c. B.C., three types of new millstones were introduced to improve this work. Their movable parts, which were always the upper ones, were so heavy that the squeezing movements just described were no longer necessary. The first of these was a millstone with a rectangular hopper, which was rocked by a lever, adapted to barley and spelt with hard hulls, which was found predominantly in Greece and in the Alps. The second was a cylindrical grindstone, turned by fitting handles, and better for hard wheat, frequently found in Spain. Finally, a bi-conic grindstone, turned by human or animal power, for soft wheat and other grains, was introduced in Italy and, afterwards, preferred almost everywhere in the large cities. The only one of these millstones that was capable of being transformed into a hydraulic mill was the cylindrical grindstone, by means of a turning shaft that passed through the inactive millstone; this technology spread rapidly in the first centuries of the empire, when it reached its peak, and so cannot be associated with a decline in slavery. But at the end of Antiquity, the other two types of mill seem to have disappeared. This development might well have been connected to the disappearance of slave labour, though alternatively it might reflect the fact that millstones were harder to obtain, and this was seen as their most efficient use.[21]

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[20] Boato *et al.* (1993).

16. *Changes in Communication Needs*

One might imagine that decreased protection from traditional piracy, and new religious and political dangers might have presented serious obstacles to Early Medieval maritime traffic, already reduced by decreased commercial interest. But this does not appear to be the case. Late antique textual sources indicate, for the first time, the operation of shipyards at Varazze, in Liguria, where they have remained ever since, partly because of their close proximity to the state-owned forest of Mount Beigua that was rich in all the timbers necessary for shipbuilding and repair. This activity seems surprising given the decline of port facilities throughout the West during the Early Medieval period. But it should be noted that the maintenance of ports had little influence on their functioning in this period because, with good weather, Early Medieval ships could be loaded and unloaded without port installations, by small boats travelling between them and the coast.

The case of land-based communications is entirely different, however. Their maintenance is indispensable, especially in alluvial areas or on steep slopes. Indeed, one landslide or the collapse of one arch of a bridge or supporting wall is enough to disrupt a long-distance transportation route. The decline in the maintenance of the road network, which was certainly not due to a decline in construction techniques, cannot be solely attributed to a lack of central intervention, in light of the fact that it had always been the responsibility of the local administration, just like the supply of vehicles and draught animals.[22] Rather, I think it is possible to see an active change in road use resulting from the different priorities of the local administration, which no longer had to pay heed to the requirements of the imperial government.

This becomes obvious when one considers the true function of Roman roads. It is noticeable that in mountainous areas such as, for example, the Alpine and Apennine regions, Rome had only chosen a few of several possible routes. These had to be equipped with changing stations for animals, which allowed people to quickly pass through an area on horseback, or in light carriages that were drawn by pairs of horses, at a trot or at a gallop. It was also vital that their gradient did not exceed 5–7 per cent and that they did not consist of large numbers of turns and bends, which would slow travellers down. These roads, where the *cursus publicus* did its job, were used for the rapid movement of messengers and various magistrates, bearing news from the provinces and orders from Rome. Other travellers, including military and mercantile groups, did not tend to travel any faster than normal pace (4 km per hour). Therefore, the Romans constructed other mountainous roads, called mule-tracks (*mulattiere*), designed to accommodate loaded mules, which, like pedestrians, walk at a normal pace up to a gradient of 50%, thereby making much shorter routes possible in hilly terrain without the use of carts.

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[21] Sebesta (1976); Donner *et al.* (1994) and Procopiou and Treuil (2002).

[22] Di Paola (1999).

If this is how things were indeed arranged in the Roman period, it is hardly surprising that once the need to transmit news and rapid orders across the empire had diminished, the majority of roads became mule-tracks, and were put to other uses. Due to their less steep gradient, they had a stronger resistance to severe weather conditions and, at the same time, reduced travelling times. Carriage-road tracks which did not require extraordinary maintenance remained as they were, while those posing greater risks, or running for longer distances, were replaced by normal mule-tracks. Finally, rope bridges replaced their stone and brick predecessors, where these had collapsed into large rivers. These deliberate solutions remained economically viable until the 19th c., when the eventual invention of motor vehicles once again made the speed of vehicles an important aspect of road design.[23]

Conclusions

This brief outline has not addressed all relevant problems and has, at the same time, perhaps identified some new ones. It seems to make no sense, from the viewpoint of cultural history, to ask isolated questions about the continuity and discontinuity of individual techniques within one particular period. This does not mean that the collection of objective data is not useful, but rather that one cannot make a valid historical interpretation without taking into consideration what happens during an entire production cycle, and in the other production cycles, especially those which are similar. It is also vital to pay close attention to the economic tendencies of the period in question and to set these against a broad socio-economic background. Finally, contemporary taste and wider existential culture must be considered. Above all, it is necessary to identify the antecedent trends and customary practices from which the technical change under consideration derives, and also successive developments that can be related to it.

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[23] Mannoni (2004).

Among the other problems that arise, one is more obvious: the necessity for the archaeologist to have a wider explanatory scheme before they begin their research, a scenario which they have in mind when analysing the archaeological indicators of production, exchange and consumption. With such a scenario in mind, it will be easier for them to notice characteristics that might otherwise have eluded them, and will encourage them to pose questions relating these characteristics to finds and to paleo-environmental data, in order to verify their presence or absence. In this way, each scholar makes observations about matters of which he has some knowledge. This is important to studies of technology, in which contextual knowledge (even if hypothetical and only probable) dramatically increases one's ability to make objective observations. Scholarly argument can then be used to examine whether an explanatory context holds, or if it can be improved.

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BIBLIOGRAPHIC ESSAYS

TECHNOLOGY IN LATE ANTIQUITY: A BIBLIOGRAPHIC ESSAY

Philip Bes

Introduction

This bibliographic essay aims to present a representative overview of the available literature on technology in the period, *ca.* A.D. 300–700. The essay is not intended to serve as an exhaustive corpus of bibliographic references, but as a basic framework, from which further references can be found. The article consciously strays beyond Late Antiquity in many places, including Early Imperial or Hellenistic studies, and references to Early Islamic work. This has been necessary owing to the fact that, in some cases, research has been carried out on a specific technological application in the Early Roman period but has not been extended to cover Late Antiquity. This may be explained either by the accidental survival of evidence from the earlier period or a lack of scholarly research into the topic for Late Antiquity; but because many technologies change only slowly, this work is still very relevant.

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Theory & Method

The technology of the Roman world was for a long time characterised as stagnant, for the large part relying upon existing knowledge and lacking innovation. Basing their work on classical texts, some scholars have tended to think of the Roman period as a pale imitation of the more brilliant Classical and Hellenistic Age, when greater advances were made in mathematics and the 'sciences'. More recently, a number of scholars, the most prominent being Kevin Greene, have pleaded for the abandonment of this 'stagnation perspective', basing their arguments on the proliferation of archaeological discoveries over the past 4 to 5 decades. The evolution of these viewpoints has been connected to a concurrent archaeological re-evaluation of the Roman economy. This has contradicted much of Moses Finley and A. H. M. Jones' text-based model of the Roman economy, which had stressed the negative effects of slave labour and aristocratic autarchy on technological innovation. Rural survey, as much as urban excavation, has revealed not only technological development, but evidence of large-scale capital investment in technology by the very people it was thought had neglected such practical economic behaviour. Of course, where studies of technological development are concerned, Late Antiquity has suffered not only from pro-Hellenistic bias, but also from the common perception that it was a period of 'decline'; many enthusiasts for early Roman technology are still downbeat regarding the technology of the 4th–6th c. A.D., and ignorant of fieldwork from the East. However, whilst a number of regions certainly experienced a technological recession, other areas enjoyed continuity, innovation, and expansion of technological expertise. In other words, the debate has hardly begun and a number of issues remain to be discussed.

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A number of contemporary writers display some degree of technical knowledge, or technical interest in different crafts. Procopius reveals an understanding of the hydraulic properties of masonry; Cassiodorus discusses paper and a water clock (*Variae* I.45) in great detail; and Isidore of Seville includes numerous entries on mechanical devices. Technical manuals were still popular. Cassiodorus translated 'Pythagoras the musician, Ptolemy the astronomer, Nicomachus the arithmetician, Euclid the geometer, Plato the theologian, Aristotle the logician, and…the mechanician Archimedes' (*Variae* I.45). Some were still being written: by Faventius, imitating Vitruvius; Palladius writing an agricultural manual; Julian of Ascalon assembling a practical rulebook for town planning; and several authors compiling military manuals, such as the anonymous *De Rebus Bellicis*, and that of Vegetius who, for instance, discusses the use of weaponry. Anthemius of Tralles wrote on conic sections and burning glasses (the first lost, the second only partially extant), while Isidore of Miletus wrote a commentary on earlier building treatises (now lost).

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POWER SOURCES & ENGINEERING

Historians of power supply have traditionally either seen the period as suffering from an abundant supply of slave labour, which discouraged labour-saving projects or devices, or as characterised by the rise of the watermill (based on its frequent appearances in the literary sources). However, Wikander has recently argued that the diffusion of the watermill took place in the Early Imperial period, even though it continued to spread to new areas in Late Antiquity. The adoption of the lateen sail in the later period can be seen as an innovative use of power, athough it is hard to gauge what the impact of this was in practice. Finds of technical devices are very rare. Bilge pumps have been discovered in shipwrecks, but otherwise it is usually necessary to rely on textual descriptions, and assume that the inventions they describe remained in use when they later turn up in the Islamic East. This is partly the case because there are probably fewer relief depictions from the Late Roman period than the Principate. Complex irrigation devices are frequently easier to identify in the archaeological record. It seems that the tradition of royal technological 'wonders' was kept alive by the likes of Anthemius of Tralles (Agathias, *Hist.* 5.6–9). We are better informed regarding military devices, thanks to military treatises, even if some of the inventions they describe never left the drawing board. The remains of surveying equipment have not been studied for the 4th–6th c. A.D., though the high quality of imperially-financed monuments and the writing of treatises demonstrate that professional training was still very much alive. Therefore, a study of prestigious monuments could well produce useful results.

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EXTRACTION

The study of late antique extraction techniques can be undertaken by using texts although, to date, it has largely been limited to the study of building remains and, in a few cases, the quarries from which building materials were extracted. Changes in the supply of freshly-cut stone seem to be the critical factor underlying the great use of recycled building blocks in Late Antiquity. In some regions, the use of freshly-cut stone carried on regardless, for instance, in the rural houses and churches of Syria. In other areas, such as parts of western Asia Minor, the principal building methods included the use of rubble (from quarry tips?) and, occasionally, brick in walls. The use of *spolia* from monumental buildings was widespread. The extraction of multi-coloured marble, which had been diffused throughout the Mediterranean during the Principate, came to an end in the 3rd c. A.D. The 4th–6th c. A.D. witnessed the exploitation of a much more limited number of sites. Porphyry ceased to be exploited in the 4th c. A.D., although the marbles of Proconnesus, Thessaly, and a number of other sites in Greece and Asia Minor continued to be transported far and wide. Meanwhile, the quarries of the Troas reached their peak in the 4th–5th c. A.D. (Sodini (2002) 131). In contrast to the Early Imperial period, we have no clearly identified metal mines datable to Late Antiquity, with the exception of Bir Um Fawakir in Egypt, where gold was extracted. Literary evidence points to metal mines in the Taurus, along the eastern frontier, and in parts of Illyricum, which have yet to be discovered. Lead isotope analysis may go some way to identifying sources of silver, though only survey and excavation will be able to confirm the extent of their exploitation.

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ARTISANAL PRODUCTION

We are fortunate to know quite a lot about the context of artisanal production in Late Antiquity. The *Notitia Dignitatum* and the legal codes describe the organisation of government factories producing certain goods. Government regulations, preserved in the same sources, document the activities of late antique guilds, though we know rather less of their Early Medieval successors. Craftsmen are also extensively mentioned, as a class, in the sermons of John Chrysostom, and in certain saint's lives, such as *The Life of Simeon the Fool.* The latter give us an idea both of the social status of the artisans and the scale of their productivity. Occasionally, urban inscriptions and funerary texts attest the presence of trades and their guilds in East Mediterranean cities (Zimmermann (2002)), with Korykos showing a wide diversity in artisans' professions. Julian of Ascalon and a few other writers discuss the urban areas within which different groups of artisans were permitted to manufacture goods. Archaeological remains of workshops and associated production waste are fairly common, thanks to the abandonment of many urban settlements in the period that immediately followed Late Antiquity.

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Pottery

Late antique pottery production continued much as it had done in Early Roman times. Amphorae retained their traditional function as vessels used to transport and store agricultural produce, wine, oil, garum and the like, although there was far less morphological diversity than in Early and Mid-Roman periods. Standardised tablewares were still produced using refined clays, and decorated with a slip. They were also still fired in an oxidising kiln atmosphere, a tradition that was to last into the late 7th or even early 8th c. A.D. Glazing was re-introduced during the 7th c. A.D. This technique had initially been used on a relatively modest scale in the Late Hellenistic and Early Roman periods, and may have been practised during the Mid-Roman period. It has been suggested that moulds were used in part of the production process of at least some of the widely traded red-slipped tablewares (African and Phocaean Red Slip Wares). This has also been suggested for some of the earlier, Late Hellenistic-Early Roman tablewares, so does not necessarily represent a new development. Coarse cooking ware continued to be produced, though by way of a more refined technology, which became available with the adoption of soap-stone vessels in North Italy in the 6th c. A.D. Brick production became especially important to imperial architecture, which relied on it for a great number of monumental buildings from the 4th to 6th c. A.D.

A partial collapse in the scale of all types of production may have occurred in many regions in the course of the 7th c. A.D. Wheel-turned pottery disappeared from Britain in the 5th c., possibly together with kiln-fired pottery. At the same time, handmade cooking wares were already being manufactured on the island of Pantelleria. The end of the Empire brought about the cessation of brick production, and in the words of Wilson, "massive economic contraction" in northern Europe, although in Northern Italy and at Rome, brick production continued into the early 8th c., even though builders increasingly relied on recycled materials.

Our knowledge of pottery is of course based not only on the artefacts themselves, but also on the archaeology of the production infrastructure. However, the evidence is scant and geographically diffuse, which means that some stages of the production process have not always been fully understood. The state of knowledge about amphorae, tablewares and other categories of pottery is more advanced in the western regions of the late antique world than it is in the East, and Bonifay's recent contribution (2004) concerning Tunisia is a case in point. However, the discovery of tableware kilns at Sagalassos, and the interdisciplinary approach adopted by work on this site, informs us in great detail about the production process of pottery; from the first stage of quarrying the raw clay, to the final, firing stage.

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TEXTILES & BASKETRY

The preservation of textiles and other organic materials is dependent on specific climatic conditions. Egypt has been shown to possess extraordinarily good conditions for the preservation of textiles, especially in burial contexts. Papyri have also been found there in great quantities. Therefore, it is not surprising that a substantial amount of the evidence for antique textiles and basketry comes from this region. Late Antiquity is particularly well represented among the 'Coptic' textiles. Elsewhere, such materials have not been preserved in large quantities and are generally only found in a small number of well-preserved tombs, or other specific contexts. Depictions on mosaics, figurines, or sarcophagi usually represent the only way of approaching the topic, although their genre and the social classes for whom they were intended need to be born in mind. Literary sources give some idea of the products in circulation, but only go into detail regarding the production process in the cases of imperial cloth-dyeing (in murex purple) and the silk trade, which from the mid-6th c. A.D. was carried out within the Roman Empire. Further, there are very few illustrations of production devices, and these mainly exist on perishable materials, although finds relating to textile production have been discovered in a row of late antique shops at Tralles. More is known about cloth treatment and washing, thanks to easily recognisable structural evidence for dyeing and fulling.

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Bone & Ivory

Late antique ivory has attracted a good deal of scholarship, for the simple reason that it was preserved in sacral contexts in western churches: as part of church treasuries, or even as reliquaries. These sources provide large, well-preserved pieces that do not exist for earlier periods. Bone and ivory has been less commonly studied on site, although the topic is receiving increasing attention.

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Other Materials

Woodwork is the least well known of the late antique crafts, despite it being one of the most technologically basic. It attracted little interest from late antique authors and its remains have barely survived outside of Egypt. Although a certain amount can be inferred from the study of iron tools, almost nothing is known about woodmanship. Meanwhile, studies have not been undertaken on the Egyptian material to gauge working and decorative techniques. However, scholars are carefully studying water-logged sites in the West to attain a more nuanced understanding of the use of wood; in products, tools and buildings. Sculpture does not share these problems. Although scholars have traditionally found it difficult to identify correctly Late Roman sculpture, a considerable corpus of material is now available. Most of our knowledge of technology used in stone-carving comes from studying these pieces: tools can be discerned from marks left by them on stone. The set of tools found in a 4th c. sculptor's workshop at Aphrodisias so far represents an exceptional find. The 3rd c. A.D. saw great changes in monumental sculpture, with a massive reduction in the amount of carving, and the disappearance of naturalistic style from all but a few workshops. In many cases, late antique epigraphy is poorly executed, though in both sculpture and text-carving there are very great local variations in competence. Epigraphic trends would appear to have been strictly localised, probably depending on patterns of patronage: whereas in some places professional text carvers seem to have disappeared, in others, for example 7th c. A.D. Ravenna, some of the finest specimens of Late Antiquity were produced. The study of jewellery and other dress accessories reveals a high degree of technical precision in crafts that combined many of the technologies listed so far. Graves and church treasuries provide us with many examples of these crafts, which seem to exhibit little decline in quality of execution and continue to show signs of experiment and adoption of new techniques.

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Construction & Building

Although well-preserved remains of building sites and depictions of them are rare, we do have the standing remains of buildings, as well as some technical literature on contemporary practices. Nonetheless, the history of building technologies in Late Antiquity is very difficult to unravel. One must cast aside the notion that the use of *spolia* was a sign of simpler, poorer-quality building techniques: *spolia* were frequently re-cut, or hidden carefully under mortar and marble, so it does not follow that it diminished the quality of building work. However, clear changes in building technology did take place. Quite apart from their incorporation of *spolia*, the late antique walls in many central Mediterranean cities sometimes seem less carefully built than their classical predecessors, with those in secular monumental buildings being notably asymmetrical, and those in restored buildings containing an odd mixture of ornamentation. In contrast, as Luke Lavan observes, the imperial monuments in Trier, Rome, Constantinople or Milan, and private villas, urban *domus*, and even some village houses of the East, reveal a high degree of competence in terms of planning, design and materials used.

Thus, as Lavan argues in his paper, one can find even in the same city, technological innovation existing alongside the use of less sophisticated techniques. Late antique fortifications are an example of the former. Similarly, the water supply system of Constantinople was arguably the most sophisticated of all time. A tradition of urban building on artificial terraces was maintained at Rome (St Peter's), Jerusalem (Nea Church), and Constantinople. Specialised structures continued to be built: the components of forts might have been less distinct, but the elements of churches were ever better defined. At the highest level, continuity with earlier Roman traditions is clear to discern, along with, in some cases, a refinement of earlier skills: the extensive use of window glass may have been an innovation of the period, and there were surely others. Conversely, in the north of the Empire in the 5th c., we see the spread of new building technologies, using wood and other organic materials. They have been studied far less extensively than technologies using stone, and have only been detected in the West.

It is fair to point out that the majority of work on late antique building has been carried out by architectural historians, who have focused on answering quite advanced technological and aesthetic questions. Detailed studies of the building trade are rare: Bardill's work on brick stamps being a notable exception. There is still much work to be done: on mortar and the organisation of building gangs on large monumental projects to name but two areas.

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Agricultural Technology & Foodstuffs

Agricultural technology can be studied using literary sources, such as the manuals of Palladius. However, given the immense variation in agricultural practices and economic trajectories in different parts of the Roman Empire, the best way to study this technology of production would seem to be through rural survey and excavation work. Survey work on deserted landscapes in Tunisia, Tripolitania, Syria, Jordan, and Israel has revealed a great deal about site structures, including irrigation and pressing devices, and animal mangers, while paleobotanical evidence has stimulated some discussion of changing crop types in Britain. The excavation of ordinary farms is still rare outside Britain, making studies of rural production difficult, though the discovery of long scythes on western sites has pointed to an interesting late antique innovation. Excellent work has been done on the production of *garum* and salsamenta in the Iberian Peninsula. Here, fish-tanks and features of the wider infrastructure have been found at several locations, and are not only of Early Imperial date.

Generally speaking, late antique rural technology continued Early Roman trends. Consequently, there are only a few serious studies of late antique agricultural technology. One area that has been studied extensively is press technology, using the easily recognisable structural evidence from the regions described above. It is clear by now that a strictly chronological and linear replacement of old techniques with new ones did not take place. Both David Mattingly's extensive work (e.g. 1995) in Tripolitania, and Tamara Lewit's paper in the present volume, make it perfectly clear that although press techniques had evolved, the screw press was not a ubiquitous feature of Late Antiquity. The invention of this device in the Late Republican period did not fully supplant the use of lever-and-weight and lever-and-windlass techniques. The continued use of diverse and, in some cases, age-old techniques, such as treading, requires further investigation. The crisis of the countryside seen in many regions at the end of Late Antiquity coincides with obvious technological changes. There were some changes in productive strategies, such as a preference for goats over cattle, in some regions, and a tendency to use simpler rather than complex technologies, though which were still based on late antique antecedents.

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Transport

Until recently, the adoption of the camel as a major means of overland transport, and the gradual disappearance of monumental streets from Early Islamic cities, has been deemed by some the most important development in late antique transport. Meanwhile, others have focused on the role played by the stirrup in the emergence of a more effective cavalry. The significance of both of these ideas is based on logical theorising, or experiment, and not primarily on the study of late antique society. Indeed, archaeological, literary and epigraphic evidence attests that the Roman road network was maintained into the 6th c. A.D. in the East, both in the countryside and within cities, and that the urban *souk* was a post-antique development. Obviously, the replacement of Roman roads with packhorse tracks in the Early Medieval West was an important development which had its origins in this period. There is some evidence for the introduction of public stepped roads in 6th c. Anatolia, which might imply that animal transport was also gradually being preferred to wheeled transport there. Nevertheless, late antique transport as a whole is a hugely neglected area of research, despite the existence of stuctural remains of bridges and roads.

It is important not to concentrate on land transport alone. The Mediterranean world continued to rely on water-borne transport, particularly ships, to transport goods. Imperial harbours continued to be built and maintained in Late Antiquity, though perhaps with less concern for their monumental appearance. This was also an age of innovation in ship-building technology, with the introduction of the lateen sail and the frame-first construction, along with numerous other minor changes. The recent discovery of a fleet of 5th c. A.D. ships at Cagliari, as well as the recovery of well-preserved river boats in other parts of the Empire, are immensely important—they can tell us a great deal more than most wrecks and literary descriptions about the technological know-how behind late antique sea transportation. We are indebted to artistic representations for information on rigging, of which some, though by no means all, realistically depict the upper parts of a ship.

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Military

In Late Antiquity, as earlier, the military was still recognised as community where technological innovation and competence were highly valued. New weapons included Roman *plombata* throwing darts and the *francisca* throwing axes, and an increasing use of lances for cavalry. A characteristic of the period is the extent to which technologies were adopted by diffusion from neighbouring peoples, whom Roman armies had to face in battle, which is true for the last two innovations named. The adoption of simple spangenhelms and helmets of the Intercisa type are also noteworthy, but as the adoption of something rather less complex than what went before. The somewhat off-beat innovations suggested by *de rebus bellicis* have long attracted the attention of scholars. The manual of Vegetius might seem more practical, but contains a large amount of material derived from earlier authors, while the manual of Maurice tells us more about the practices of its time (late 6th–7th c. A.D.). Historical descriptions of battles can provide nuggets of valuable information, although it is necessary to take into account distortions of literary genre in such texts. Consequently, work on late antique weaponry is focused primarily on the archaeological evidence, which mainly consists of grave goods. Experimental archaeology has much to offer scholars studying the usage of weaponry, although its results do not represent objective truths.

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Information & Communication Technology

Information technology has generally been the most neglected area in any discussion of late antique technology. As Lavan discusses in his paper, this 'information technology' included a raft of techniques inherited from the Early Empire: financial record-keeping, the minute-taking of meetings, the archiving of laws and legal settlements, shorthand records of orations/sermons, and postal networks operated by dispatch riders. While certain technologies, such as the codex and stenography, came to prominence from the 4th c. A.D., they were not new in and of themselves. The same can be said of maps and *notitiae*, though there is slightly more information about them in Late Antiquity than in earlier periods. For information technology and communication, we are of course wholly dependent upon texts, including original manuscripts such as codices. Occasionally, cartographic elements (icons representing cities) turn up on mosaics, though the only extensive map-mosaic known to date is that from Madaba. Archaeologists have occasionally excavated archives, making it possible to say something about their internal organisation: for example, at Petra. Overall, however, the disinterest of the majority of scholars represents a significant barrier to a greater understanding of information technology in Late Antiquity. The only scholars to have paid attention to this subject area are iconographers, or other specialists of niche disciplines, and they have not normally had technological considerations at the forefront of their minds.

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Change over Time and its Explanation

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METAL TECHNOLOGY IN LATE ANTIQUITY: A BIBLIOGRAPHIC NOTE

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Research into metal technology in Late Antiquity has arguably been neglected. Within wider studies of ancient metallurgy, scholarship has tended to focus on the origins and early development of techniques and practices in specific regions of the ancient world, such as Anatolia, Mesopotamia and the Near East, where the occurrence of metal ores upon the earth's surface led to their earliest exploration and the first experiments in the field of metallurgy. In part, this approach may be justified by the fact that the evolution of metal technology was very slow and gradual, being the last raw material to be exploited in ancient times, except in Anatolia, where the earliest metallurgical finds have been associated with pre-ceramic levels. Consequently, it is important for scholars of Late Antiquity to keep abreast of general synthetic publications reflecting this wider context, in addition to the specialised literature devoted to their own period.

Recent interest in late antique metal technology has not led to an even coverage of all geographical regions and chronological periods. For example, in the West, there has been considerable interest in this period, with much research being undertaken on the continuation of techniques and practices throughout all historical ages, including Late Antiquity and the Early Medieval period. Conversely, in the East, scholarly attention seems to have focused mainly on the Bronze Age to the Early Iron Age, and then jumped forward to Islamic sites, thereby leaving the Classical and Early Medieval periods largely uncovered.

The available evidence comprises both excavated material, and the material derived from the scientific analysis of metal finds and related waste products. In general, archaeo-metallurgical structural remains (e.g. furnaces, workshops, hearths, working floors, storage pits) are poorly preserved and often not very spectacular. In these circumstances, the archaeological record is often not of a high quality, especially for classical and late antique sites in the East, where modern excavators mostly aim to discover monumental architectural structures and sculptural decoration. However, to produce a record useful for studies of technology,

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it is important to document all of the typical residues formed during different stages of metalworking during an entire production cycle, from the mining of the ore to the eventual finishing of an object, taking into account the circulation and daily use of the finished product. In order to understand the production of any metal at a given time, in a given area, one needs to know the applied techniques, and the location, size, extent and socio-economic context of the activities involved in each step of the production line (mining, smelting, working). Last, but not least, it is important to consider the consumption purposes of a product, in terms of the level of demand that might exist and its intended use. Such factors are again determined by specific socio-economic settings.

Scientific analyses of metal finds and related (waste) products have resulted in a wide range of geological, geochemical and geophysical observations, related to mining provenance and production/working processes. Unfortunately, these studies have tended to communicate their results in very specialised vocabulary, making it often difficult to gauge from them the exact nature, extent, scale and time-span of the technological procedures involved in metal production and the social, economic and ecological contexts within which they were carried out, both at regional and site level. Such specialist work requires disciplined historical interpretation in order to be applied to studies of ancient technology. One complicating factor is metal recycling. As in all periods, this can affect the nature of analyses, and should be constantly borne in mind.

Our current knowledge of late antique metallurgy is uneven. We know very little of late antique metal mining, as very few remains dating from this period have been identified. This leads to a suspicion that the period saw a far less intensive and less organised exploitation of metal resources than had earlier periods. Where metalworking in general is concerned, we know the most about iron, especially from the Early Medieval West. This is most probably related to the boom in the iron industry in the Early Imperial era, which led to the mass production and, equally, mass consumption of this latest metal to be exploited. Excavation reports have paid more attention to small finds of iron and copper alloy, though more systematically in the West than in the East, as a result of differing excavation interests and strategies. Likewise, smithies and other urban metal workshops are better documented in the West than in the East in the classical era and Late Antiquity. The prestige of silver finds has resulted in an impressive number of artefact studies, leading to a substantially greater understanding of the consumption of precious metal, and also to the identification of significant technological changes in production during Late Antiquity.

Very few major technological innovations have been documented for Late Antiquity. This can be explained in part by the lack of specific scholarship devoted to this period, and, at the same time, by the slow and gradual development of metal production techniques. Except for pattern-welding, which increased somewhat in complexity, other metal techniques seem to have stagnated.

Further functional research on metal objects and the whereabouts of their production, especially in the East, needs to be conducted, in order to fully understand the nature and extent of late antique metal technology. Future research into technology would also do well to focus not only on the context of production but also on consumption patterns. The boom in the use of metal objects in all layers and sectors of society, is a notable feature of Early Imperial times, but continuing mass consumption is also present in the late antique period, as suggested by excavation catalogues published in the West and the East, all indicating similar consumption trends.

General Multi-Period Syntheses: Metal as an Archaeological Material

Both R. F. Tylecote's publications, mentioned below, and those of Giardino, serve as authoritative reference works in a field that is becoming known as the modern science of archaeometallurgy. Henderson looks at an equally full range of antique metals and ores—including copper, iron, tin, zinc, lead, gold, silver, bronze and brass, while, at the same time, attempting to locate antique mines. This approach is similar to that adopted by Healy. In these general works, the full spectrum of metallurgical techniques is discussed, from smelting, to refinement and purification. Overall, the case studies and periods discussed tend to focus on early developments in metallurgy, and deal to a far lesser extent with Late Antiquity, especially for the East. On the other hand, Bénazeth and White offer good references to further reading on the period, but again over-emphasise the West. The work of Bilgi serves as excellent further reading, covering all metallurgical aspects in full chronological order. Further, it is very useful for the East, as it deals with the classical and Byzantine periods in Asia Minor, and includes a substantial bibliography.

Tylecote R. F. (1976) *A History of Metallurgy* (London 1976). Tylecote R. F. (1962) *Metallurgy in Archaeology* (London 1962). Henderson J. (2000) *The Science and Archaeology of Materials. An Investigation of Inorganic Materials* (London and New York 2000) 208–96. Healy J. F. (1978) *Mining and Metallurgy in the Greek and Roman World* (London 1978). Bénazeth D. (1992) *L'art du metal au début de l'ère chrétienne* (Paris 1992). White J. R. L. (1962) *Medieval Technology and Social Change* (Oxford 1962). Bilgi Ö. (2004) *Anatolia, Cradle of Castings* (Istanbul 2004) 145–249. Giardino C. (1998) *I metalli nel mondo antico. Introduzione all'archeometallurgia* (Rome and Bari 1998).

Late Antique Mining

As mentioned above, references to late antique mining districts are scarce, regional, not systematically documented, and pre-occupied with the West. References in Klappauf clearly illustrate the outstanding German tradition, similar to the situation in Britain, and give detailed information on the exploitation of silver, lead, copper and iron ores. This North German study describes systematic mining and smelting activities since the 9th c. A.D. Shepard offers a good general introduction to ancient mining in general, from the dawn of history, to the final years of the Roman Empire. For the region of Lombardy, in the North of Italy, the publication of Cucini Tizzoni, which covers the exploitation of the Bienno area during Late Antiquity, is recommended. Apart from dealing with extractive metallurgy in the area, the work of Benoit and Brunstein considers to late antique and Early Medieval smelting remains (pp. 93–140) and forging activities (pp. 141–82).

Klappauf L. (2004) "Rammelsberg near Goslar—Northern Germany. 3000 Years old mining districts waits to be explored", in *Archaeometallurgy in Europe. Proceedings of a conference held in Milan, 24–26 September 2003* (Milan 2003) 645–54. Shepherd R. (1993) *Ancient Mining* (London-New York 1993). Cucini Tizzoni C. and Tizzoni M. (1999) *La miniera perduta. Cinque anni di ricerche archeometallurgiche nel territorio di Bienno* (Breno 1999). Benoit P. and Brunstein P. (1983) ed. *Mines, carrières, et métallurgie dans la France médiévale* (Paris 1983).

LATE ANTIQUE METAL PRODUCTION

Copper/Bronze/Brass

1. *Syntheses*

General processes and techniques in copper, bronze and brass working were practised throughout Antiquity, such as hammering, casting, embossing, chasing, engraving, inlaying, enamelling and gilding. Yet engraving, inlaying, gilding and enamelling, especially the use of the niello technique, peaked in late antique ecclesiastical contexts, as illustrated by the work of Marlia Mango and others. Bailey deals with the details of brass production in the West, and Garenne-Marot *et al.* gives excellent references to copper and bronze working in the East.

Mango M. M. (1994) "The significance of Byzantine tinned copper objects", in *Thymiama sti mneme this Laskarinas Mpoura* (Athens 1994) 221–28. Bailey J. (1999) "The production of brass in Antiquity with particular reference to Roman Britain", in *2000 Years of Zinc and Brass*, ed. Craddock P. T. (British Museum Occasional Paper 50) (London 1999) 7–26. Garrenne-Marot L., Bertholon R., Bell B. and Lacoudre N. (1998) "Métal et techniques de fabrication d'un lot d'objects en alliage base-cuivre de l'époque omeyyade (VIII^{e} siècle)", in *Les métaux antiques: travail et restauration* (Monographies Instrumentum 6), Feugere M. ed. (Montagnac 1998) 29–38).

2. *Key monographs*

Regional studies dealing with copper, bronze and brass technology tend to be scarce, especially for the East. However, Hauptmann deals briefly with Early Islamic copper smelting, with reference to mining, in Oman, for the 9th and 10th centuries A.D.

Hauptmann A. (1985) "5000 Jahre Kupfer in Oman. Band 1. Die Entwicklung der Kupfermetallurgie vom 3. Jahrtausend bis zur Neuzeit", in *Der Anshnitt* 4 (Bochum 1985) 95–103.

Iron

1. *Syntheses*

All general works dealing with iron technology in late antique times focus on the West, and ignore the East. Mangin (2004) and Gurin address the topic from a general technological point of view, dealing with the Roman to Late Roman periods in the West; they discuss the provenance of iron and its minerals, the reduction process, and archaeological finds related to smithing activities, whilst attempting to put iron production into its socio-economic context. Pleiner (2000) deals specifically with Early Medieval ironworking in Europe, and discusses in particular the Late Roman to Early Medieval transition (pp. 272–80). Fluzin *et al.* offers a general introduction to all different aspects of ancient iron technology, regardless of its specific period of production, and is equally applicable to the evidence from late antique sites. Also worthwhile because of their general technological approach are Kronz, Amreim and Binder, and Senn-Lauder, who reflect perspectives developed on late antique German sites. Serneels, Magnusson, Pleiner (1969) and Gömöri should be consulted for the wider North-East European area. Mangin (1994) offers excellent references to eastern French sites, again placed within a wider regional context, but only focuses very briefly on late antique examples.

Mangin M. (2004) ed. "Le fer", in *Collection Archéologiques*, ed. A. Ferdière (Paris 2004). Gurin M. (1996) "Sintering in the time of blooms-formation in the ancient and medieval metallurgy of iron", in *The Importance of Ironmaking* 88 (1996) 121–27. Pleiner R. (2000) *Iron in Archaeology. The European Bloomery Smelters* (Praha 2000). Fluzin Ph., Ploquin A. and Serneels V. (2000) "Archéometrie des déchets de production sidérurgique: moyens et methods d'identification des différents elements de la chaîne opératoire directe", in *Gallia* 57 (2000) 101–21. Kronz A. (2004) "Ancient iron production compared to Medieval techniques in Germany: Fayalitic slag and elemental mass balances", in *Archaeometallurgy in Europe. Proceedings of a Conference held in Milan, 24–26 September 2003* (Milan 2003) 555–64. Amreim H. and Binder E. (1997) "Metallgewinnung und Schmiedekunst im Frühen Mittelarter", in *Die Alamannen* (Stuttgart 1997) 359–70. Senn-Lauder M. (1998) "Schlacken und Schmelzgefässe als Spiegel des Metallgewerbes im alten Zug", in *Tugium* 14 (1998) 113–54. Serneels V. (1998) "La chaîne opératoire de la sidérugie", in *Recherches sur l'économie du fer en Méditerranée nord-occidentale*, edd. M. Feugère and V. Serneels (*Monographies Instrumentum* 4) (Montagnac 1998) 7–44. Magnusson G. (1995) "Iron production, smithing and iron trade during the Late Iron Age and Early Medieval Ages (ca 5th–13th centuries)", in *Archaeology East and West of the Baltic* (Symposium Sigtuna 1991), ed. I. Jansson (Stockholm 1995) 61–70. Pleiner (1969) "Experimental smelting of steel in early medieval bloomeries", in *Památky archeologické* 60 (1969) 459–87. Gömöri J. (1999) ed. "Traditions and innovations in the early medieval iron production", *Papers of the 1997 Sopron and Somogyfajsz Conference, Dunaferr* (Sopron and Somogyfasjz 1999). Mangin M. (1994) ed. "La sidérurgie ancienne de l'Est de la France dans son contexte européen", *Colloque Besançon 1993, Annales littéraires de l'Université de Besançon* 536 (Paris 1994).

2. *Key Monographs*

Not surprisingly, a number of key monographs have dealt with applied technologies in the West, whilst again neglecting the East. The publications of French and Swiss sites provide outstanding methodological exemplars of how to describe, catalogue, present and interpret finds associated with the production of ancient iron. Eschenlohr and Serneels (1991) is an outstanding work on an Early Medieval iron production site in Switzerland, dealing with vegetation and charcoal studies, mines and iron minerals, smelting furnaces, the specific functions of furnaces and smaller reduction sites. It illustrates, from a morphological point of view, a successful attempt to quantify smithing cakes. Eschenlohr (1998) provides a similar approach for the Swiss smithing site of Develier-Courttételle, which was occupied during the 7th an 8th centuries A.D. A good example of how one can study the spatial organisation of a Romano-Celtic smithy is provided by Anderson *et al.* This work makes special reference to different types of metallurgical debris created by this type of metal-working activity. Dieudonné-Glad describes a Late Roman smelting area with a related smithy in France. Serneels (1998) also describes a Late Roman iron and copper working site in France, indicating the co-existence of metal-working activities in both metal types. Finally, Leroy offers an overview of iron working activities prior to the invention of the blast furnace, for the region of Lorraine.

Eschenlohr L. and Serneels V. (1991) "Les bas fourneaux Mérovingiens de Boécourt, Les Boulies (JU, Suisse)", in *Cahier d'archéologie jurassiene* 3, ed. F. Schifferdecker (Porrentruy 1991). Eschenlohr L. (1998) "Les ateliers de forgerons de Develier-Courttételle (Jura, Suisse)", in *Les métaux antiques: travail et restauration* (Monographies Instrumentum 6) Feugere M. ed. (Montagnac 1998) 19–22. Anderson T.J., Agustoni C., Duvauchelle A., Serneels V. and Castella D. (2003) *Des artisans à la campagne. Carrière de meules, forges et voie gallo-romaines à Chables (FR)* (*Archéologie fribourgeoise* 19) (Fribourg 2003). Dieudonné-Glad N. (1997) "Les Oulches, a late Roman iron smelting and smithing workshop", in *Early Ironworking in Europe. Plas Tan y Bwlch Occasional Paper* (Maentwrog 1997) 17–20. Serneels V. (1998) "Les ateliers sidérurgiques d'Autun-Lycée Militaire", in *Les métaux antiques: travail et restauration* (Monographies Instrumentum 6) ed. M. Feugere (Montagnac 1998) 23–27. Leroy M. (1997) "La sidérugie en Lorraine avant le haut fourneau, l'utilisation du minearai oolitique en réduction directe", in *Monographie du Centre de Récherches Archéologiques* (Paris 1997).

The German tradition (Guyan, Wollschläger and Dehnke) focuses predominantly on mining and smelting. It is similar to the Belgian approach of Van Doorselaer, and the Italian and Spanish studies mentioned below (Coretti) (Larrazabal). This work has tended to ignore smithing activities in Late Antiquity (except for Guyan). The same approach is followed in studies of Late Antiquity that are devoted to eastern Europe (Gömöri, Pleiner 1992, 1965 and 1985), which deal solely with ore working (mining and smelting). This can perhaps be explained by the geological factors in eastern Europe. These define an archaeological landscape in which almost no surface remains are visible (Mušič) and archaeologists are strongly dependant upon geophysical research.

Guyan W.U. (1965) *Schaffhauser Eisenhütten und Hammerschmieden im Mittelalter* (Schaffhausen 1965). Wollschläger B. (1992) "Ein Eisenverhüttingsplatz der späten römischen Kaiserzeit und frühen Völkerwanerungszeit bei Göhlen, Kr. Ludwigslust", in *Ausgrabungen und Funde* 37.3 (1992) 152–53. Dehnke R. H. (1970) "Ein Siedlungs- und Eisenverhüttungsplatz der spätrömischen Kaizerzeit von Westernholz, Kr. Rothenburg", in *Wümme. Nachrichten aus Niedersachsens Urgeschichte* 39 (1970) 268–74. Van Doorselaer A. van (1971) "Primitieve Eisenverhüttung in Belgien", in *Early Medieval Studies* 3 (*Antikvariskt Akriv* 40) (1971) 31–36. Coretti A. (1991) "Metallurgia medievale all'isola d'Elba", in *Quaderni del Dipartimento di Archeologia e Storia delle Arte—Università di Siena* (Florence 1991).Larrazabal J. (1996) "Iron mining and metallurgy during the Roman and Medieval periods in Zamora (Spain)", in *The Importance of Ironmaking. Technical Innovation and Social Change* vol. 2 (Stockholm 1996) 167–75. Gömöri J. (1985) "Iron ore utilization in the Carpathian Basin up to the Middle Ages with special regard to bloomeries in Western Transdanubia", in *Neogen Mineral Resources in the Carpathian Basin* (Budapest 1985) 323–55. Pleiner R. (1992) "Bemerkungen zu einigen Schmelzversuchen in frümittelalterlichen Rennöfen in der Tschecheoslowakei", in *Experimentelle Archäologie. Bilanz* 1991 (Oldenburg 1992) 323–29. Pleiner R. (1965) "Das Eisenverhüttung bei den Slawen im frühen Mittelalter", in *Vita pro Ferro* (Festschrift fur R. Durrer) (Schaffhausen 1965) 135–62. Pleiner R. (1985) "The Bloomeries of the Romano-Barbarian period at Varín, North Slovakia", in *Archeologické rozhledy* 37 (1985) 467. Mušič B. (2000) "Results of geophysical prospecting on Prehistoric and Late Roman sites associated with iron metallurgy; case studies: Cvinger near Meniška vas and Ajdovščina above Rodid (Slovenia)", in *Iron, Blacksmith and Tools. Ancient European Crafts. Acts of the Instrumentum Conference at Podsreda (Slovenia) in April 1999*, (*Monographies Instrumentum* 12) ed. M. Feugère (Montagnac 2000) 109–21.

Precious Metals

1. *Syntheses*

On the production of precious metals in Late Antiquity and, in particular, gold and silver plates, the works of Kent and Painter or Donald Strong, although 30 years old, still remain excellent starting points, whereas Hendy offers more recent further reading. Hauser and

Volbach illustrate nicely a more general approach to the production of silver luxury goods.

Kent J. P. C. and Painter K. (1977) edd. *The Wealth of the Roman World: Gold and Silver A.D. 300–700* (London 1977). Strong D. E. (1966) *Greek and Roman Gold and Silver Plate* (London 1966). Hendy M. F. (1989) "The administration of mints and treasuries, fourth to seventh centuries, with an appendix on the production of silver plate", in Hendy M. F. ed *The Economy, Fiscal Administration and Coinage of Byzantium* 6 (Northampton 1989) 1–18. Hauser S. R. (1992) "Spätantike und frühbyzantinische Silberlöffel: Bemerkungen zur Produktion von Luxusgüttern im 5. bis 7. Jahrhundert", in *Jahrbuch für Antike und Christentum Ergänzungsband* 19 (Münster 1992). Volbach W. F. (1962) "Silber- und Elfenbeinarbeiten vom Ende des 4. bis zum Anfang des 7. Jahrhunderts", in *Beiträge zur Kunstgeschichte und Archäologie des Frühmittelalters. Akten Zum VII Internationalen Kongress für Frühmittelalterforschung 21.–28. September 1958* (Cologne 1962) 21–36.

2. *Key Monographs*

Regional studies dealing with the production of late antique precious metals (such as the works of Baratte *et al.* and Baratte 1993 & 1988, Susan Boyd and Kaufmann-Heinimann) all tend to focus on consumption, i.e. the use and circulation of silver artefacts, with little reference to production. An exception to this is the work of Mango and Bennet, which combines historical, archaeological and scientific approaches to study the largest ever find of Roman silver. Werner's contribution, in the publication of Craddock and Hughes, offers specific references to late antique gold technology in eastern Europe. Moreover, the publication of Craddock and Hughes, included below, gives an excellent overview of smelting technology in general, with specific references to zinc, copper, iron, silver and gold technology, though it over-emphasises pre-classical sites and areas.

Baratte F., Lang J., La Niece S. and Metzger C. (2002) *Le trésor de Carthage: contribution à l'étude de l'orfèvrerie de l'Aniquité tardive* (Paris 2002). Baratte F. (1993) *La vaiselle d'argent en Gaule dans l'antiquité tardive (III^e–V^e siècles)* (Paris 1993). Baratte F. (1988) ed. *Argenterie romaine et byzantine: actes de la table ronde, Paris 11–13 october 1983* (Paris 1988). Boyd S. A. (1992) "A 'metropolitan' treasure from a church in the provinces: an introduction to the study of the Sion Treasure", in *Ecclesiastical Silver Plate in Sixth Century Byzantium*, edd. Boyd S. A. and M. M. Mango (Washington DC 1992) 5–38. Kaufmann-Heinimann A. (1999) "Eighteen new pieces from the Late Roman silver treasure of Kaiseraugst: first notice", in *JRA* 12 (1999) 333–41. Mango M. M. and Bennet A. (1994) *The Sevso Treasure: Part I. Art Historical Description and Inscriptions, Methods of Manufacture and Scientific Analysis* (Journal of Roman Archaeology Supplementary Series 12.1) (Michigan 1994). Werner M. R. (1996) "The archaeological evidence for gold smelting at Kraku'Lu Yordan, Yugoslavia, in the Late Roman period", in *Furnaces and Smelting Technology in Antiquity* (British Museum Occasional Paper 48) edd. Craddock P. T. and Hughes M. J. (London 1996) 219–27.

Lead

1. *Syntheses*

On a general level, the studies of Boulaika and Hofmann, although over 30 years old, offer a superb overview of the provenance, use and technology of lead and its alloys in Antiquity. Little or no attention is paid however to Late Antiquity, and a more general introduction to lead working in the East is still needed.

Boulakia J. D. C. (1972) "Lead in the Roman world", *AJA* 76 (1972) 36–64.
Hofmann W. (1970) *Lead and Lead Alloys* (Berlin 1970).

2. *Key Monographs*

Again, for regional studies, it seems that work has only been published on lead technology in the West. The work of Cochet is essential for anyone interested in ancient lead production as such. This manual deals with the physical properties of lead, and the full production and working processes it underwent, until it was transformed into finished artefacts. The value of this work is clear when compared, for instance, with the article of Ploquin *et al.* dealing with Early Medieval lead smelting in the South of France. This paper presents a brief technological overview for lead smelting and working, demonstrating, at least for the western part of the Roman Empire, that little or no technological change took place during Late Antiquity.

Cochet A. (2000) "Le plomb en Gaule romaine. Techniques de fabrication et produits", in *Monographies Instrumentum* 13, ed. Feugère (Montagnac 2000).
Ploquin A., Allée Ph., Bailly-Maître M. C., Baron S., de Beaulieu J. L., Carignan J., Laurent S., Lavoie M., Mahé-Le Carlier C., Peytavin J. and Pulido M. (2003) "Medieval lead smelting on the Mont Lozère, southern France", in *Archaeometallurgy in Europe. Proceedings of a conference held in Milan, 24–26 September 2003* (Milan 2003) 635–44.

(Late Antique) Archaeometallurgical Remains

As mentioned in the introduction of this paper, archaeological remains and structures deriving from smelting and metalworking are poorly preserved and often neglected, or simply not recognised by field archaeologists. Regardless of one's specific chronological, geographical or cultural field of interest, the publications and further references provided by Rehder (1999, 1987 and 1994) offer excellent general and specific reading on ancient pyrotechnical remains in the field of metallurgy. Equally important, though short, is the manual of Hans Gert Bachmann on the identification of slag remains related to different metals and specific metallurgical activities. Penniman *et al.* is a specific typological study of smelting installations in Great Britain in Late Antiquity, which illustrates well the need for future research in this field, although the paper was published nearly 50 years ago.

Rehder J. E. (1999) "High temperature technology in Antiquity. A sourcebook on the design and operation of ancient furnaces", in Hauptmann A., Pernicka E. Rehren T. and Yalçin Ü edd. *The Beginnings of Metallurgy. Proceedings of the International Conference "The Beginnings of Metallurgy", Bochum 1995* (Bochum 1999) 305–17. Rehder J. E. (1987) "Natural draft furnaces", in *Archeomaterials* 2.1 (1987) 47–58. Rehder J. E. (1994) "Blowpipes versus bellow in ancient metallurgy", in *JFA* 21 (1994) 345–50. Bachmann H.-G. (1982) "The identification of slags from archaeological sites", in *Institute of Archaeology Occasional Publication* 6 (London 1982). Penniman T. K., Allen I. M. and Wootton A. (1958/1959) "Ancient metallurgical furnaces in Great Britain to the end of Roman occupation", in *Sibrium* 4 (1958/1959) 97–127.

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GLASS TECHNOLOGY IN LATE ANTIQUITY: A BIBLIOGRAPHIC NOTE

Veerle Lauwers

Subject Syntheses: Glass as an Archaeological Material

Studies of late antique glass tend to fall into two groups: those which concentrate on the geochemical component; and typological/chronological works. Although, up till now, no exhaustive study has been undertaken on the relationship between these two areas, a number of works, listed below, provide an overview of information on either the typo-chronological aspect or the geochemical characteristics of ancient glass. *Tout feu, tout sable* (2001) and *Cœur de verre* (2003) are exceptions to this rule. These exhibition catalogues tried, in an exemplary way, to fit the mixed geochemical data into the general (but complicated) *chaîne opératoire* of antique glass production. While scholars tend to find Henderson (2000) the most appealing guide, Wedepohl's book (2003) is the ideal geochemical starter-kit for the glass student—a clear text, with illustrations and graphs (28 tables with analyses for comparison in an appendix), though it omits the abundant archaeological examples Henderson gives a noteworthy description of glass production in Abbasid and Ayyubid Syria, at al-Raqqa (76–90).

Von Saldern's *magnum opus* (2004) synthesises the history of glass, from its invention at the end of the 3rd or beginning of the 2nd millennium B.C. somewhere in the Middle East, up to the transformation of the West Roman Empire into the Frankish empire, in around A.D. 400, and the shift from the usage of 'Late Roman' to 'Early Byzantine' glass in the Near East. *Antikes Glas* describes the evolution of glass technology and typology, giving the reader a clear idea of how mankind learned to handle this vitreous material. The exhaustive chapter on blown glass (218–528), with a discussion of its possible origins, also gives an overview of the different vessel types, as well as late antique glass-working methods (cutting, engraving, diatreta, *fondi d'oro*...). When compared with Von Saldern, J. Philippe's (1970) monograph is less complete. However, although slightly outdated, the volume capably describes the broad trends attested in glass technology during the entire Byzantine

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period. The proceedings of the 1993 congress on *Le verre de l'antiquité tardive et du haut moyen age* contain contributions on material from the West to the East, from Britain and Dorestad to Russia and Jordan, ranging from the 4th–9th centuries A.D.

Roman, Byzantine and Early Medieval glass; 10 B.C.–700 C.E. Ernesto Wolf Collection (2001) is much more than a catalogue. This exceptionally well-researched book offers superb colour photographs, alongside detailed technological descriptions of selected vessels that are explained within their historical and geographical contexts. Also very useful are the extensive glossaries that describe equipment and tools, vessel shapes, characteristics of production and decoration, and a discussion of the vessel shapes attested to date. This catalogue is a key reference to understanding late antique glass morphology and glass working, although the reader must be aware of the current discrepancy between the outstanding quality of the glass described in this catalogue and the reality of the fragmentary plain glass excavated on late antique sites.

General Works on Late Antique Glass: Foy D. (1995) ed. *Le verre de l'antiquité tardive et du haut moyen âge. Typologie, chronologie, diffusion (18–19 novembre 1993, Guiry-en-Vexin)* (Val d'Oise 1995). Stern E. M. (2001) *Roman, Byzantine and Early Medieval Glass: Ernesto Wolf Collection* (Ostfildern 2001); Von Saldern A. (2004) *Antikes Glas* (München 2004); Philippe J. (1970) *Le monde byzantin dans l'histoire de la verrerie* (Bologne 1970);

Geochemical Introduction to Glass Studies: Henderson J. (2000) *The Science and Archaeology of Materials. An Investigation of Inorganic Materials* (London–New York 2000) 21–108; Wedepohl K. H. (2003) *Glas in Antike und Mittelalter. Geschichte eines Werkstoffs* (Stuttgart 2003).

The Segments of the Glass Production Process: Foy D. and Nenna M.-D. (2001) edd. *Tout feu, tout sable. Mille ans de verre antique dans le Midi de la France* (Aix-en-Provence 2001); Foy D. (2003) ed. *Cœur de verre. Production et diffusion du verre antique* (Gollion 2003).

The Nature of the Evidence

The sources for the study of glass are problematic. High status items are recovered from tombs, and whole chunks of raw glass from ships. But the glass retrieved from archaeological sites probably does not reflect its use. There is a large hiatus in the ordinary glass that is found on sites, especially in the Levant, that has doubtless been affected by the recycling of fragments. This means that only sudden destruction deposits give a real reflection of glass use within a given area. The detection of secondary workshops is difficult, given that these structures were insubstantial, meaning that they are probably under-represented in the reports from many extensively-excavated urban sites.

Late Antique Glass Production

The Making of Raw Glass

During the last 15 years, the late antique period has attracted much attention within glass studies. Whereas in the early years of glass research, approaches were often very stylistic and art historical, they are now dominated by a chemical approach. The conference proceedings edited by Nenna (2000), and Foy and Nenna (2003), stress the existence of rigorous trade systems that provided the West (where the primary production of raw glass did not take place) with chunks of glass ready for re-heating in occidental and oriental (Freestone *et al.* (2002)) kilns. The actual blowing of the vessels also took place in these secondary workshops. Recently, however, chemical evidence for limited primary glass production in the Roman West has been found, as demonstrated by Wedepohl (2003) for the Hambacher Forst in the 5th c. A.D., and Jackson, Joyner, Booth, Day, Wager & Kilikoglou (2003) for Coppergate in the late 2nd and early 3rd centuries A.D. The *Mappae clavicula* shows us that by the 12th c., primary glass production was well integrated into western society.

The move from soda lime to plant ash as the main alkali flux source occurred at some point during the 9th c. (Dijkman *et al.* 2003 and Fiori 2004). Making glass using plant ash was a somewhat difficult process, as illustrated by the failed batch recorded at Bet She'arim (Freestone and Gorin-Rosen 1999) and the ongoing 'recyclage' of Roman glass (Dussart *et al.* 2004). However, Henderson *et al.* (2004) show how strontium isotopes can serve as a reliable means of distinguishing between the different alkaline sources.

General: Dijkman A., Velde B., Janssens K. and Aerts W. (2003) "Change in silica sources in Roman and post-Roman glass", *Spectrochimica Acta* Part B (2003) 659–67; Fiori C. (2004) "Chemical composition of glass and its raw materials: chronological and geographical development in the first millennium A.D.", in *When Glass Matters*, ed. M. Baretta (Florence 2004) 151–94; Tolaini F. (2004) "*De tinctio omnium musivorum*: Technical recipes for glass in the so-called Mappae clavicula", in *When Glass Matters*, ed. M. Baretta (Florence 2004) 195–219.

Geochemical Glass Groups Identified in the West: Foy D., Picon M., Vichy M. and Thirion-Merle V. (2003) "Caractérisation des verres de la fin de l'Antiquité en Méditerranée occidentale: l'émergence de nouveaux courants commerciaux", in *Echanges et commerce du verre dans le monde antique*, edd. D. Foy and M.-D. Nenna (Montagnac 2003) 41–85; Picon M. and Vichy M. (2003) "D'Orient en Occident: l'origine du verre à l'époque romaine et durant le haut Moyen Âge", in *Echanges et commerce du verre dans le monde antique*, edd. D. Foy and M.-D. Nenna (Montagnac 2003) 17–31.

Geochemical Glass Groups Identified in the East: Freestone I. C., Gorin-Rosen Y. and Hughes M. J. (2000) "Primary glass from Israel and the production of glass in Late Antiquity and the Early Islamic period", in *La route du verre. Ateliers primaires et secondaires du second millénaire av. J.-C. au Moyen Âge*, ed. M.-D. Nenna (Lyon 2000) 65–83; Freestone I., Greenstone R. and Gorin-Rosen Y. (2002) "Byzantine and Early Islamic glassmaking in the Eastern Mediterranean: production and distribution of primary glass", in *Hyalos, Vitrum, Glass. History, Technology and Conservation of Glass and Vitreous Materials in the Hellenistic World*, ed G. Kordas (Athens 2002) 167–74; Thirion-Merle V., Nenna M.-D., Picon M. and Vichy M. (2003) "Un nouvel atelier primaire dans le Wadi Natrun (Égypte) et les compositons des verrres produits dans cette region", *Bulletin de l'Association française pour l'Archéologie du verre* (2003) 21–24; Dussart, O., Velde, B., Blanc, P.-M. and Sodini, J.-P. (2004) "Glass from Qal'at Sem'an (Northern Syria): the reworking of glass during the transition from Roman to Islamic compositions," *Journal of Glass Studies* 46 (2004) 67–84; Henderson J., Evans J. A., Sloane H. J. and Leng M. J. (2004) "The use of oxygen, strontium and lead isotopes to provenance ancient glasses in the Middle East", *JAS* 32.5 (2004) 665–73.

Primary Production in the West: *Britain*: Cool H. E. M., Jackson C. M. and Monaghan J. (1999) "Glass-making and the sixth legion at York", *Britannia* 30 (1999) 147–61; Jackson C. M., Joyner L., Booth C. A., Day P. M., Wager E. C. W. and Kilikoglou V. (2003) "Roman glass-making at Coppergate, York? Analytical evidence for the nature of production", *Archaeometry* 45 (2003) 435–56. *Germany*: Wedepohl K. H., Gaitzsch W. and Follmann-Schulz A.-B. (2001) "Glassmaking and glassworking in six Roman factories in the Hambach Forest, Germany", in *Annales du 15e congrès de l'association Internationale pour l'histoire du verre: Corning, New York* (Corning 2003) 56–61; Wedepohl K. H. (2003) "Die Glasrezepte sowie der antike und mittelalterliche Handel mit Glas und Glasrohstoffen", in *Glashütten im Gespräch. Berichte und Materialien vom 2. Int. Symposium zur archäologischen Erforschung mittelalterlicher und frühneuzeitlicher Glashütten Europas*, ed. P. Steppuhn (Lübeck 2003) 92–96.

Primary Production in the East: *Israel*: in general: Foy D. (2003) "Les ateliers primaires syro-palestiniens", in *Cœur de verre. Production et diffusion du verre antique,* ed. D. Foy (Gollion 2003) 28–31. Specific sites: Freestone I. and Gorin-Rosen Y. (1999) "The great glass slab of Beth She'Arim, Israel: An Early Islamic glass making experiment?", *JGS* 41 (1999) 105–16; Gorin-Rosen Y. (2000) "The ancient glass industry in Israel: summary of the finds and new discoveries", in *La route du Verre: Ateliers primaires et secondaires de verriers du second millénaire av. J.-C. au Moyen Âge,* ed. M.-D. Nenna (Lyon 2000) 49–64; Gorin-Rosen Y. (1995) "Hadara, Beit Eli'ezer", *IEJ* 13 (1995) 42–43. *Egypt*: Nenna M.-D. (2000) "Ateliers primaires et secondaries en Égypte à l'époque gréco-romaine", in *La route du Verre: Ateliers primaires et secondaires de verriers du second millénaire av. J.-C. au Moyen Âge,* ed. M.-D. Nenna (Lyon 2000) 97–112; Nenna M.-D. (2003) "Les ateliers égyptiens à l'époque grèco-romaine", in *Cœur de verre. Production et diffusion du verre antique,* ed. D. Foy (Gollion 2003) 32–33. Specific site: Saleh S. A., George A. W. and Helmi F. M. (1972) "Studies of glass and glass making processes at Wadi el-Natrun Egypt in the Roman period 30 B.C. to 359 A.D.", *Studies in Conservation* 17 (1972) 143–72.

Secondary Workshops

The publications of the excavations at Jalamet el Asafna (1988) and *L'Atelier de verriers d'Avenches* (2001) are landmarks in glass studies. Both are of great scientific value, due to their detailed analysis of the abundant finds; consequently, Amrein's monograph, despite its chronological focus, cannot be omitted. The data from these two publications has been plotted in E. M. Stern's article, "Roman glassblowing in a cultural context" (1999), from which one gets a clear view of how little has changed in the glass industry since the invention of glass-blowing (even today). For the Levant, the Byzantine workshop of Bet She'an, although not published in great detail, provides important clues regarding the production of the most common vessel glass, as does the excavation of the 4th–5th c. workshop of Samaria-Sebaste. In Alexandria, traces of glass production have been found, though no longer *in situ*. The related finds indicate the production of beads and other kinds of jewellery in glass. For the West, a large late antique/Early Medieval workshop has been unearthed under the Crypta Balbi.

General: Stern E. M. (1999) "Roman glassblowing in a cultural context", *AJA* 103 (1999) 441–84; Amrein H. (2001) *L'Atelier de verriers d'Avenches. L'artisanat du verre au milieu du 1er siècle après J.-C.* (Lausanne 2001).

Archaeological Sites by Region: *Britain*: Price J. (2000) ed. *Glass in Britain and Ireland: A.D. 350–1100* (London 2000). *Gaul*: Foy D. (1988) ed. *Le verre medieval et son artisanat en France méditerranéenne* (Paris 1988); Foy D. and Sennequier G. (1989) edd. *À travers le verre: du moyen âge à la renaissance* (Rouen 1989); Foy D. and Sennequier G. (1991) edd. *Ateliers de verriers de l'Antiquité à la période pré-industrielle* (Rouen 1991); van Geesbergen D. (1999) "Les ateliers de verriers dans le nord de la Gaule et en Rhenanie (1er–4^{e} siècle après J.C.)", in *Artisanat et productions artisanales en milieu rural dans le provinces du nord-ouest de l'Empire romain*, ed. M. Polfer (Luxemburg 1999) 105–24; Rütti B. (1991) *Die Römische Gläser aus August und Kaiseraugust* (Muttenz 1991); Pouille D. and Labaune F. (2000) "L'atelier de verrier antique de Cesson-Sévigné", in *La route du verre. Ateliers primaires et secondaires de verriers du second millenaire av. J.-C. au Moyen Âge*, ed. M.-D. Nenna (Lyon 2000) 125–46. Spain: Termini Storti R. (1994) "Una produzione vetraria tardoantica a Sevegliano (agro di Aquileia)", *AquilNost* 65 (1994) 5–14. Italy: Saguì L. (2000) "Produzioni vetrarie a Roma tra V e VII secolo", in *Annales de 14e Congrès de l'Association Internationale pour l'Histoire du Verre* (Venice-Milan 2000) 203–207; Sternini M. (1989) "A glass workhop in Rome (4th–5th century A.D.)", *Kölner Jahrbuch für Vor- und Frühgeschichte* 22 (1989) 105–14; Manacorda D. (2001) *Crypta Balbi. Archeologia e storia di un paesaggio urbano* (Rome 2001); Rottloff A. (2000) "Gläser und Reste von Glasverarbeitung aus Ostia", *RM* 107 (2000) 365–74. Greece and Balkans: Déroche V. and Pétridis P. (1993) "Delphes 3. Agora romaine et villa sud-est", in "Travaux de l'école française en Grèce en 1992", *BCH* 117 (1993) 641–44; Sagadin M. (1999) "Late antique glass workshop in Kranj (Slovenia)", *Bulletin Instrumentum* 9 (1999) 31. Asia Minor: Smith R. R. R. and Raté C. (1998) "Archaeological research at Aphrodisias in Caria", *AJA* 102 (1998) 225–50; Czurda-Ruth C. (2004) "Glass aus Ephesos: Hanghaus 1 und eine Werkstätte des 6 Jahrhunderts n. Chr auf der Agora", in *Annales du 16e Congrès de l'Association Internationale pour l'Histoire du Verre* (Nottingham 2004) 158–61; von Saldern A. (1980) *Ancient and Byzantine Glass from Sardis* (SardisMon 6) (Cambridge, Mass. 1980); Lauwers V. Degryse P. and Waelkens M. (forthcoming) "Evidence for Anatolian glassworking in Antiquity: the case of Sagalassos (S-W Turkey)", *JGS* (forthcoming). Syria: Lebanon: Foy D. (2000) "Un atelier de verrier à Beyrouth au début de la conquête islamique", *Syria* 77 (2000) 239–90. Palestine: Weinberg G. D. (1988) *Excavations at Jalame: Site of a Glass Factory in Late Roman Palestine* (Columbia, Missouri 1988); Gorin-Rosen Y. (2000) "The ancient glass industry in Israel: summary of the finds and new discoveries", in *La route du Verre: Ateliers primaires et secondaires de verriers du second millénaire av. J.-C. au Moyen Âge,* ed. M.-D. Nenna (Lyon 2000) 49–64; Crowfoot G. M. (1957) "Chapter XIII. Glass", in *The objects from Samaria III*, edd. J. W. Crowfoot, G. M. Crowfoot and K. Kenyon (London 1957) 403–21; Mazor G. and Bar Nathan R. (1998) "The Bet She'an excavation project 1992–1994 Antiquities Authority Expedition", *Expeditions and Surveys in Israel* 17 (1998) 7–38; Fischer A. (1999) "Glass Production Activities as Practised at Sepphoris, Israel (37 B.C.–A.D. 1516)", *JAS* 26 (1999) 893–905. Egypt: Rodziewicz M. (1984) *Alexandrie III: les habitations romaines tardives d'Alexandrie à la lumière des fouilles polonaises à Kôm el-Dikka* (Warsaw 1984); Haas C. (1997) *Alexandria in Late Antiquity. Topography and Social Conflict* (London 1997); Nenna M.-D. (2000) "Ateliers primaires et secondaries en Égypte à l'époque gréco-romaine", in *La route du Verre: Ateliers primaires et secondaires de verriers du second millénaire av. J.-C. au Moyen Âge*, ed. M.-D. Nenna (Lyon 2000) 97–112.

Glass Working

The first books mentioned above (except for Lierke (1999)) all give broad interpretations and explanations of antique glass-making technology. Lierke, in her turn, suggests that shaping glass on a potter's wheel was an alternative production method to glass-blowing, which was not obligatory. Meanwhile, Bimson (1980) pinpoints a difference between the pontil marks on Late Roman vessels and Anglo-Saxon examples, a technical detail that has implications for the actual process of glass working, as well as its chronology.

On the decoration of Early Islamic glassware, the monographs and articles of Allen (1995) and Kröger (1998) are especially worthy of mention. The excellent catalogue of Carboni (2001) includes Umayyad and Abbasid glassware and introductory essays on their decorative technology, especially the major technical achievements of gilding and lustre painting (also cfr. Ward (1998) supra). The article of Foy, Picon and Vichy extends this Umayyad and Abbasid typology with archaeometrical results. *Nishapur glass of the Early Islamic Period* (1995) is the standard work on Abbasid glass and its chemical composition.

Roman and Late Antique Glass Technology: *synthetic works*: Mendera M. (1991) *Archeologia e stroria della produzione del vetro preindustriale* (Florence 1991); Sternini M. (1995) *La Fenice di Sabbia. Storia e tecnologia del vetro antico* (Bari 1995); Stiaffini D. (1999) *Il vetro nel medioevo. Tecniche, strutture, manufatti* (Rome 1999); Spaer M. (2001) *Ancient Glass in the Israel Museum: Beads and Small Objects* (Jerusalem 2001); Stephan H. G. (2003) "Glasschmelzgefäße. Grundzüge der Entwicklung von den Anfängen im alten Orient bis zur Neuzeit", in *Glashütten im Gespräch. Berichte und Materialien vom 2. Int. Symposium zur archäologischen Erforschung mittelalterlicher und frühneuzeitlicher Glashütten Europas*, ed. P. Steppuhn (Lübeck 2003) 136–62; *Key studies*: Bimson M. (1980) "Ring 'Pontil Marks' and the empontilling of a group of seventh-century Anglo-Saxon glass", *JGS* 22 (1980) 9–11; Buora M. (1998) "La circulazione vetraria nell'Italia nordorientale nel periodo tardoantico e la produzione di un maestro vetraio a Sevegliano", in *Il vetro dall'antichità all'età contemporanea: aspetti tecnologici, funzionali e commerciali* (Milan 1998) 165–72; Lierke R. (1999) *Antike Glastöpferei: ein vergessenes Kapitel der Glasgeschichte* (Mainz 1999); Stern E. M. (2002) "The ancient glassblower's tools", in *Vitrum-Hyalos-Glass*, ed. G. Kordas (Athens 2002) 159–65.

Islamic Glass Technology: Allen J. (1995) "Investigations into marvered glass: I", *Oxford Studies in Islamic Art* 10 (1995) 1–30; Kröger J. (1995) *Nishapur Glass of the Early Islamic Period* (New York 1995); Kröger J. (1998) "Painting on glass before the Mamluk period", in *Gilded and Enamelled Glass from the Middle East*, ed. R. Ward (London 1998) 8–11; Carboni S. (2001) *Glass from Islamic Lands* (New York 2001); Foy, D. Picon, M. and Vichy, M. (2003) "Verres omeyyades et abbassides d'origine égyptienne: les témoignages de l'archéologie et de l'archéometrie", in *Annales du 15ᵉ Congrès de l'Association Internationale pour l'Histoire du Verre* (Corning 2003) 138–43.

Glass Re-cycling

Re-cycling was most probably based on the re-melting of the waste produced by the glass workshop itself, hence the small quantity of moils and knock-off that tend to be found, and the distinctive geochemical data (lead isotope mixing lines) that have been gathered (Degryse *et al.* 2006). Bearing in mind that there is evidence for the existence of such trade, there must have been a demand for glass sherds (especially in Late Antiquity and the Early Medieval period). In the shipwreck of Serçe Limani (11th c.), a large quantity of cullet was found, as was also the case in the Sardis shops, E12 and E13, which probably served a retailing function. Foy, Stern and Keller all use more or less the same epigraphic sources to describe the 'invention' of recycling and the practical organisation of gathering cullet in the 1st c. A.D., while Keller tries to take things one step further by looking for the context in which church glass was recycled.

Archaeological Evidence: Stern E. M. (1999) "Roman glassblowing in a cultural context", *AJA* 107 (1999) 450–51; Foy D. (2003) "Recyclages et réemplois dans l'artisanat du verre. Quelques exemples antiques et médiévaux", in *La ville et ses déchets dans le monde romain: rebuts et recyclages*, edd. P. Ballet, P. Cordier and N. Dieudonne-Glad (Montagnac 2003) 271–76; Keller D. (2004) "Social and economic aspects of glass recycling", in *Proceedings of the Fourteenth Annual Theoretical Roman Archaeology* Conference, edd. J. Bruhn, B. Croxford and D. Grigoropoulos (Oxford 2004). *Specific sites*: Bass G. F. (1984) "The nature of the Serçe Limani glass", *JGS* 26 (1984) 64–69; Crowfoot J. S. (1990) *The Byzantine Shops at Sardis* (Archaeological Exploration of Sardis 9) (Cambridge, Massachusetts 1990) 78–86.

Geochemical Evidence: Degryse P., Schneider J., Lauwers V., Muchez P., Haack U. and Waelkens M. (2006) "Analytical evidence for glass 'recycling' using Pb and Sr isotopic ratios and Sr-mixing lines: the case of Early Byzantine Sagalassos", *JAS* 33, 4 (2006) 494–501.

Window panes

For decades, the study of window panes was stagnating. Little attention was paid to this tiresome material category. Most studies encountered traces of un-identifiable production techniques, or got stuck in endless discussions on how and when window panes were made. Starting from the remarks made by the 12th c. German monk, Theophilus, most authors have tried to compare the cylinder blowing process by which sheet glass was produced (Harden 1959 and 1961) with the casting technique (Boon 1966) and the production of crown window panes (Meyer

1989). Despite the authority of the authors, these discussions prove that neither of these production methods have un-disputable diagnostic features. At a recent conference on window panes (Bavay/Sars-Poteries 2005), no uniform conclusion was reached on what archaeological remains can tell us regarding manufacturing procedures, although the work presented was both abundant and refreshing. However, through experimental archaeology, Denis Allen gave some indication that, in future, a thorough classification of tool markings and the techniques of producing window panes might be possible. Finally, the paper of Barag, based on the Aphrodisias copy of Diocletian's Edict, examines the different kinds of glass known to the Romans—Alexandrian, Judaean and two different types of window glass of varying quality—and their maximum prices.

General: Harden D. B. (1959) "New light on Roman and Early Medieval window glass", *Glastechnische Berichte* 23 (1959) 8–16; Harden D. B. (1961) "Domestic window glass: Roman, Saxon and Medieval", in *Studies in Building History. Essays in Recognition of the Work of B. H.* ***ST.*** *J. O'Neil*, ed. E. M. Jope (London 1961) 39–63; Boon G. C. (1966) "Roman window glass from Wales", *JGS* 8 (1966) 41–45. Hawthorne J. G. and Smith C. S. *Theophilus: On Divers Arts* (Chicago 1963). Meyer C. (1989) "Crown window panes: Constantinian or Justinian?", in *Essays in Ancient Civilization presented to Helene J. Kantor*, edd. Leonard A. and Williams B. B. (Chicago 1989) 213–19; Foy D. (2005) ed. *De transparentes spéculations: vitres de l'Antiquité et du Haut Moyen Âge (Occident-Orient)* (Bavay 2005).

Classical Authors: Theophilus (1963) *On Divers Arts* (Chicago 1963) (reprint New York 1979); Barag D. (1987) "Recent important epigraphic discoveries related to the history of glassmaking in the Roman period", in *Annales du 10e Congrès de l' Association Internationale pour l'Histoire du Verre* (Amsterdam 1987) 109–16; Allen D. (2002) "Roman window glass", in *Artefacts and Archaeology*, edd. M. Aldhouse-Green and P. Webster (Cardiff 2002) 102–11.

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AGRICULTURE

WATER INTO WINE: TRADE AND TECHNOLOGY IN LATE ANTIQUITY

Michael Decker

Abstract

Wine production in the late antique Levant depended on the existence of large internal and overseas markets. Estate owners and farmers reacted to the flourishing late antique wine market by investing heavily in the land. This input included the widespread adoption of, hitherto under-utilised, more efficient wine presses. Accompanying the use of the screw press in wine production was the simultaneous spread of the saqiya. This technology required significant capital outlay and a deep pool of technically skilled craftsmen. The phenomenon thus provides a glimpse of the pace of technological development at least partly driven by market conditions and the spread of technology in the countryside.

The agrarian expansion of the Levant throughout the 4th–6th centuries A.D., broad in its geographical sweep and deep in its socio-economic impact, underpinned the vibrant urban life of Late Antiquity. A vast, ever-growing archaeological corpus continues to support the hypothesis that the eastern provinces of the Roman Empire witnessed widespread rural settlement peaks accompanied by, in many instances, unprecedented urban prosperity. While the boom period was apparently short, peaking from the 5th c. into the 7th c., there remain numerous features of society and economy awaiting fuller investigation.[1] Among these is the role that technology played in everyday life, particularly the relationship between economy and technology. This is a natural question to ask today, given the correlation between economic growth and technological advancement that has become an assumption deeply engrained within many societies. This corollary is, in fact, modern and was nonexistent in the ancient world, as pre-industrial societies rarely had, as our current evidence suggests, any notion of progress. It is,

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[1] One of the questions that remains is what dates define this time of economic vitality within the Levant, particularly its start in the Roman period, and whether or not a similar level of economic development continued into the Early Islamic period.

L. Lavan, E. Zanini, and A. Sarantis (edd.) *Technology in Transition A.D. 300–650*
(Late Antique Archaeology 4 – 2006) (Leiden 2007), pp. 65–92

at present, difficult to generalise about the array of technologies in general use, how new technologies were developed, and what impact technological change had on society. The most fruitful approach is through a series of discreet studies that, while they may illuminate only one segment of life, can provide a broad comparative framework in which one might examine the many communities that inhabited the late antique world.

One keystone of the economic expansion of the late antique East was the trade in wine and other agricultural commodities, especially those from Egypt and Syria-Palestine. Textual data provide an important window from which to view this movement, but in recent decades the large amount of new archaeological material has offered a unique opportunity to enhance the initial impression offered by the texts. Much of the wine exported from the East flowed from the vats of presses in the provinces of Palaestina I–III and Phoenice, areas which are today wholly or partially contained within the borders of Israel. The material record from Israel is particularly impressive; much of the data that allow us to investigate technological changes in the 4th–7th centuries comes from this country. In an exploration of ancient technology on the eve of the Muslim conquests, it is only natural to examine winemaking, the processes of which have left substantial vestiges within the archaeological record.[2] The picture that emerges from such an exploration is one of the widespread use of new technologies within wine production. As exciting as technological shifts within the countryside of the East are, many questions arise about which we may only speculate. More work is needed for us to fully address these agnate issues.

The large-scale production and shipment of wine from the Levant in Late Antiquity was primarily centred on the farms of the coastal regions. At some point during Roman rule, each area from Cilicia to Egypt appears within the textual record on trade. Thus, in the 1st c. A.D., the city of Laodicea in Syria was famous for its wine, appearing in Strabo with a heavily terraced, vineyard-clad city territory.[3] The wine of Laodicea was traded as far afield as the Red Sea littoral, known from a citation within the *Periplus Maris Erythraei*.[4] In Pliny's day, varieties from Syria were sufficiently well-known to be common in Italy.[5] Cilicia also produced famous medicinal wines commented on by Galen, and from the coast of Phoenicia came the wines of Tripoli and Sarepta (Sarafand).[6] The development of the viticulture of the East continued unabated into Late Antiquity, when the written sources are again instructive and well-known. The foremost wines were those from Gaza and Ascalon, which were highly regarded: they were served at the imperial table in Constantinople as well as in the royal houses of Frankish Gaul.[7] The same wines travelled widely: we hear of them elsewhere in Gaul at this time and in North Africa.[8] Something of the export centres are known from the 4th c. *Expositio totius mundi*, a handbook written by a merchant describing the Roman world and what products one would expect to procure from region to region. The *Expositio* provides evidence for wine and oil being major products of the coastal cities of Phoenicia, as well as the Palestinian cities of Gaza and Ascalon. The latter, according to the *Expositio*, were centres engaged in trade, especially with Egypt and Syria.[9] This list by no means exhausts the textual references to 'wines of origin' which circulated throughout the Mediterranean and beyond, but it does offer a representative sample of the production and terminus centres for some of them.

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[2] It should be mentioned that the Islamic period of Mediterranean history has for several decades now been viewed as revolutionary in the realm of technology. Both Watson (1983) and Hasan and Hill (1986) have set the canon for what has become orthodoxy within scholarly circles, but has yet to be fully assessed. I am in the process of undertaking this project.

[3] 16.2.9.

Convincing though the written data are, the wine trade would have remained nothing more than an intriguing historical footnote were it not for the material record that has been accumulating over the last half century. In particular, the advancement of amphora studies has continued steadily since the publication of the fundamental work of Peacock and Williams.[10] Major publications of Late Roman sites around the Mediterranean have allowed scholars to identify a range of amphorae types that circulated widely, as well as numerous varieties that were only sparsely traded. Among the former are various Late

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[4] *Periplus Maris Erythraei* 6 (ed. and transl. Casson (1989) 52).

[5] *HN* 14.41; 15.66.

[6] Cilicia, called *abates*; Galen, *De santitate tuenda*, 5.4.15–16 (ed. Koch *et al.* (1923)); Tripoli, Caelius Aurelianus, *Celerum vel acutarum passionum* (ed. and transl. Drabkin (1950) 281).

[7] Corippus *In laudem Iustini Augusti Minoris* 3.87–88 (ed. Cameron (1976) 63).

[8] Gaul: Gregory of Tours, *Liber Historiae Francorum* 7.29 (ed. Krusch and Levison (1951) 348); North Africa, Ascalon wine: Cassius Felix, *De medicina* 42.13 (ed. Fraisse (2002) 114).

[9] *Expositio totius mundi* (ed. Rougé (1966) 164, 166).

[10] Peacock and Williams (1986).

Roman amphorae types, classified in excavations at Carthage as 'Late Roman Amphora' or LR, particularly types LR 1–5. Due to their discovery in quantity at Berenike (Benghazi) in Libya, Riley believed that these jars could be considered as a group or 'package' of containers due to their similar places of origin and chronologies.[11] Several types indeed share comparable chronologies of development, and their contents were also often alike. Although long associated with olive oil, the mixed evidence suggest that the LR 1 type jar was a regional container originating in the north-east corner of the Mediterranean and carrying an array of local products, though principally wine and oil. To date, LR 1 is the most commonly found imported container on late antique archaeological sites throughout the Mediterranean, and it appears as far afield as Axum and India.[12] The sources of several of the late antique amphorae are known. Production sites for the LR 1 type have been located on Cyprus, where recent analysis indicates multiple production centres within the hinterlands of several Cypriot urban centres.[13] Several kiln sites have been discovered there, such as that at Zygi-Petrini near Paphos, the major port of Cyprus during the Roman era.[14] Empereur and Picon have reported kiln sites strewn about the countryside of the north-eastern Levant, from northern Syria through Cilicia, former Isauria, and as far west as Rhodes and Lycia.[15] These finds require further surface investigation and excavations so that they may be certainly identified and so that data that will advance our refinement of sourcing techniques for LR 1 can be collected.

LR 2 was a rounded Aegean type. It was a multi-purpose container, used in the transport of a range of agricultural products, primarily wine and olive oil, from Greece and the Aegean Islands. LR 2 is especially prominent alongside LR 1 in the Balkans, where many of the excavated sites were part of the *limes* system which became increasingly pressured through the 5th and 6th centuries by various invading groups.[16] The high profile of LR 1 and LR 2 in military sites in the Balkans has suggested to Karagiorgou that the prevalence of these types is to be connected with changes in military supply that took place during the reign of Justinian.[17]

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[11] Riley (1979) 151.

[12] Aksum: Munro-Hay and Phillipson (1989) 314; India: personal communication E. Lyding-Will.

[13] Gomez *et al.* (2002) 33.

[14] Paphos: Papacostas (2001); Zygi-Petrini: Manning, Monks *et al.* (2000). There are many finds of LR 1 amphora throughout Cyprus, an exhaustive list is impossible, but see Rautman (2000) for some recent discoveries.

[15] Empereur and Picon (1989).

[16] Scorpan (1975); Popovic (1987) and Karagiourgou (2001) 132–39.

LR 3 belongs to the western coastlands of Asia Minor, and is one of the least studied amphorae. The jar enjoyed a wide circulation; it appears in Nubia at the excavations at Qasr Ibrim, and it travelled widely throughout the western Mediterranean as well.[18] It is generally a less well-represented type amongst the LR amphorae classes, and corresponds to a minor, but important trade component in Late Antiquity. The morphology of LR 3, with its narrow mouth and toe, suggest a container for non-viscous liquids, probably wine. We know considerably less about LR 3 than on the other vessels discussed here, and more work is required before we understand the morphological changes it underwent, its production centres, and what commodities it transported.

Perhaps the most visible set of amphorae are those tied to the wine trade of the Holy Land: the cylindrical LR 4 and bag-shaped LR 5. Like the other LR amphorae, these vessels were not restricted to wine, but it was their principal content. In addition to the wine trade from the Holy Land, the archaeological evidence continues to mount, primarily in the form of amphorae, kilns, wineries, and shipwrecks. LR 4, the so-called 'Gaza-Ascalon' jar, the *gazition* of Late Antiquity, was thus named due to its being the chief container for the famous vintages produced in the hinterland of the cities of Gaza and Ascalon on the southern Palestinian coast. Here, vineyards near the shore, and in the Negev, processed and shipped wines to the ends of the ancient world. Kiln sites producing Gaza-Ascalon jars are well attested along the coastlands of southern Palestine.[19] The distribution of this jar is geographically vast; a handle of a Gaza jar has been found at Qana in South Arabia, and there are numerous finds of this type as far west as the British Isles.[20] LR 5 shares a distribution similar to LR 4. The morphology of LR 5—squat with a rounded bottom, ring handles and wide mouth—indicates a general-purpose type designed to be stowed easily aboard a ship, conveniently filled and emptied of viscous liquids and dry goods, and stored for long periods without the need of amphorae stands. Beyond the vast circulation that LR 4 and LR 5 enjoyed in the late antique period, the technical success of LR 5 is further proved by its persistence, little modified, into the Umayyad period, where it is visible throughout the 7th and 8th centuries, notably at Pella.[21]

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[17] Karagiorgou (2001) 148–56.
[18] Mills *et al.* (1982), Pacetti (1995) 273–79.
[19] Israel (1993).
[20] Qanaa; Sedov (1992) 113; British Isles: Thomas (1959).

The above jars all serve as proxies for the circulation of wine and oil from eastern production centres, both internally within the East Roman Empire, and externally in those regions outside of imperial control. It is certain that these far-flung ceramic finds signify important and often direct contacts between easterners and the wider world. Were it not for the quantifiable data trawled from a select group of archaeological sites, these amphorae finds would appear insignificant, representing no more than casual contact, high-level gift-exchange or the chance relic of the ephemeral presence of eastern travellers or soldiers. The quantified assemblages tell a different story, one of frequent, direct, and relatively intensive contact.[22] At Arles, eastern jars formed 40 per cent of the total amphorae deposits in the early 5th c. deposits reported by Bonifay, Congés and Léguilloux.[23] The Schola Praeconum dump excavations, with material dating from the 5th c., contained LR 1, LR 3, LR 4 and LR 5 totalling 27.7 per cent of the total amphorae. LR 1 was the most common eastern type, representing 14.7 per cent of all amphorae (by weight), followed by LR 3 (7.9 per cent), LR 4 (4.1 per cent) and LR 5 (one per cent).[24] In the British excavations at Carthage, in the Vandal period deposit in Cistern 1977.1, eastern shipping containers comprised 41.13 per cent of the total pottery; the most numerous of these was LR 5 (19.2 per cent).[25] There are other assemblages from around the western Mediterranean that offer quantified data, and the above figures are repeated and amplified in numerous instances.[26] Clearly eastern bulk goods arrived in the west in quantity during the 5th–6th centuries A.D.

The hypothesis that a burgeoning wine trade was a major component of the late antique eastern economy leads to numerous questions, the foremost of which is the nature of the movement. For those of the Finley-Jones persuasion, the ceramic evidence stands for little; it is a mark of state-controlled or state-fostered movement of agricultural commodities. In this case, the East Roman army and bureaucracy would have been the primary consumers of these goods or, perhaps, local elites whose ties to the New Rome ebbed and flowed depending on politics and fashion. For 'maximalists', the movement was due to private enterprise, and the ceramic remains represent the smooth functioning of a flourishing market, healthy enough to attract foreign goods from far afield. Both views have strengths and weaknesses, and on the present data both may be cogently supported. Whether state control or free enterprise provides the better answer remains to be seen. Whichever the case, discussion of technology must occupy a place in our view of the economy. Technological changes may have engendered some economic change, were a product of that change, or some combination thereof. A fuller study of these interactions is needed before our understanding is complete.

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[21] Watson (1992) 239–40.

[22] Dark (2003) argues that Byzantine merchant activities in the West involved direct contact.

[23] Reynolds (1995) 305; Bonifay, Congés, and Léguilloux (1989) 660–63.

[24] Reynolds (1995) 327.

[25] Riley (1981) 90, tbl. 2 based on RBHS count.

[26] Reynolds (1995).

To date, the technology of amphorae production has been little scrutinised. The overriding concerns of archaeologists have resided rather in exploring provenance and distribution. By the medieval period, Byzantine amphorae show strong features of exacting standardisation in their capacities. This is most clearly seen in the case of the Serçi Limani wreck of the 11th c. where van Doorninck has argued that amphorae were carefully graduated in intervals of 3 or 5 *litrai*.[27] Van Doorninck perceived that Middle Byzantine amphorae were manufactured to exacting metrologies and filled by weight, not by volume. Van Alfen's study of the LR 1 amphorae from the 7th c. Yassi Ada wreck raises several important points. Among them, he notes the inefficiency of the LR 1 jars at Yassi Ada, compared with the LR 2 jars hauled by the same ship. This 'inefficiency' connotes a container species primarily reserved for higher value commodities.[28] Van Alfen further posited that Yassi Ada LR 1 containers may be divided into subgroups whose measurements or general vessel form, denoted by weight, indicate they were designed to carry specific products such as red wine, white wine or olive oil.[29] Unlike Hellenistic or Roman period amphorae, in which local products were strongly linked to their respective shipping containers, Late Roman vessels were thus apparently regional. We might therefore consider that LR 1 amphorae may have circulated within a context in which the consumer would have known that the jars contained wine from the north-east Mediterranean, but not the specific city or estate. One wonders then how wines of appellation, which we know circulated in Late Antiquity, were identified, since the distinction afforded by local vessels, such as the old Rhodian amphorae of the Hellenistic age, was no longer relevant.

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[27] van Doorninck (1993) 8–12.
[28] van Alfen (1996) 208.
[29] van Alfen (1996).

If Van Alfen's hypothesis proves correct, then LR 1 containers were technically more challenging to produce, requiring skilled potters capable of mass manufacture of vessels exhibiting little variation. This would, in turn, seem to demand strict oversight at some level, either within the pottery itself, or at the filling point, where vessels would presumably be weighed to determine their standard. What is more, this level of standardisation would suggest that technology was employed in a process of integration, whereby local practices in production and exchange were subsumed within greater geographic and economic unities.[30] There thus exists a distinct possibility that technology as basic as ceramic production played a significant role in shaping the economic space of Late Antiquity.

One issue that clouds our understanding of the production and use of late antique amphorae is that of re-use. The latter was a notable feature of the containers found on the Middle Byzantine Serçe Limani wreck.[31] The trend is also well-attested in Late Antiquity: the Yassi Ada ship and the 6th c. Dor D ship that wrecked off the coast of Israel also carried re-used jars.[32] The continued dependence on worn transport containers is worthy of note from a technological standpoint. It may suggest that, despite the continued transport of agricultural commodities, the supply of amphorae could not meet this demand. Were the skilled potters that produced LR 1 and LR 4 amphorae and the like at this time no longer accessible to officials and merchants? Was the technical skill required to produce these vessels otherwise lost? Were the conditions which fostered their creation in the first place drastically altered, removing the *raison d'etre* for production in this fashion? We can do no more than speculate, but it is tempting to view these developments as belonging to the late 7th or 8th c., rather than the 6th or early 7th centuries, when the north-eastern quadrant of the Levantine coast was potentially disrupted first by Persian, then by Muslim incursions.[33]

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[30] A host of questions attend this issue, namely why was this undertaken in the Levant? Did it occur elsewhere? What drove the change: was it the market, state, or some other force? These issues offer substantial promise for future research.

[31] van Doorninck (2002) 899–905.

[32] Kingsley (2003) 88 addresses re-use of amphorae in Late Antiquity in the context of the Dor D wreck.

Applied Technology Before the Muslim Conquests: Vineyard and Oliveyard

The preceding discussion briefly sketched some of the amphorae evidence supporting the widespread trade in agricultural commodities during Late Antiquity. From it, there emerges a picture of substantial material exchange between East and West, though dominated by eastern goods and eastern merchants.[34] Abundant new evidence, soundly collected and interpreted, is needed, but it is unlikely that this will radically alter the view thus far constructed. Within this larger picture there are many detectable nuances and interconnections that a close examination of the data supports. We have already witnessed a possible transformation in the technology, manufacture, and accepted definition of the amphora within the context of this eastern-dominated trade. This phenomenon affected all those involved, whether potters, farmers, merchants, soldiers or other consumers. Unsurprisingly, in the context of the Late Roman world, where cities were continually subject to the central government, we see the replacement of the cities as primary economic units by larger regional ones. The amphorae, therefore, are a natural linchpin tying nodes of production with those of consumption. In this realm possible subtle changes in organisation of production and ceramic techniques perhaps imply a real shift in the paradigm of technology, but this remains untested. At the centres of production, however, there are much more direct data showing rapid change in applied technology, and linked once again to the trade in agricultural goods flowing from the eastern provinces. The technology in use in wine and oil presses is where we find this technological change most clearly exhibited.

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[33] There is no satisfactory investigation into the end of the eastern Roman dominance of Mediterranean trade, although it is generally assumed not to long outlive the turn of the 7th c. A.D. This is in doubt, and careful works needs to be undertaken before we can muster anything resembling a conclusive picture. I am inclined to agree with the assessment of Kingsley (2003) 88 that the cycle of plagues from the mid-6th c. were not devastating to eastern trade activities, but this opinion also requires substantial and cautious review.

[34] Eastern merchant activities have attracted considerable scholarly attention, especially in the West: García-Moreno (1972) examined the Iberian case, but this is but a sample of the material dealing with eastern merchants in Spain and Gaul. On the latter, see the notable contributions of Bréhier (1903) and Lambrechts (1937) and more recently, Devroey (1995).

Olive Presses

To fully appreciate this change, a brief discussion of press evolution is required. Brun and Frankel have addressed the technical significance of oil presses in some detail.[35] Both trace the chronological development of press types and present typologies. In light of these works, the present study is restricted to a brief survey of press forms and operating principles in order to pursue the broad pace of change in the landscape of the late antique East. I have made no attempt to be exhaustive in my outlook of the press finds of ancient Palestine and Phoenicia; my own efforts in cataloguing these sites fell far short of Kingsley's 899 presses, which, alongside the work of Frankel, form the most complete body of knowledge. The handful of examples that I site below are generally dependent on the latter.[36]

Elaborate press machinery is not required for the manufacture of oil.[37] Methods of simple oil and wine production, such as treading, persisted on the subsistence level throughout antiquity and continued to be utilised into the modern period.[38] Mattingly argues that use of an oil press indicates a higher social and economic level of development and that press remains indicate surplus production.[39] Oil pressing equipment was the object of specialised production and obtained at some expense. Such capital outlay may imply marketing of the machinery's output. From Kafr Nabo in the Jebel Sim'an we possess an inscription naming the stonecutter and carpenters who built the Type 1 press there in A.D. 224.[40] The Kafr Nabo evidence further suggests that specialised workers built the village's fine subterranean double installation.

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[35] Brun (1986) and (2004), Frankel (1994) and (1999). There is a large and growing literature on ancient wine and oil presses. The latest to appear is that of Brun (2004). Frankel (1994) and (1999) are the major syntheses of press technology in the Levant; they provide the basis of the developments discussed throughout this work. I adopt a simple typology for presses, referring to the major types based on technical sophistication and chronological changes. Where more sophistication is required, I will refer to the typology established by Frankel (1999).

[36] Kingsley (1999) 68, table 3, appendix 1.

[37] Amouretti (1986) 159–61; Frankel (1999) 56–57.

[38] Brun (1986) 45; Frankel (1999) 56–57.

[39] Mattingly (1988b) 157.

[40] Callot (1984) 93.

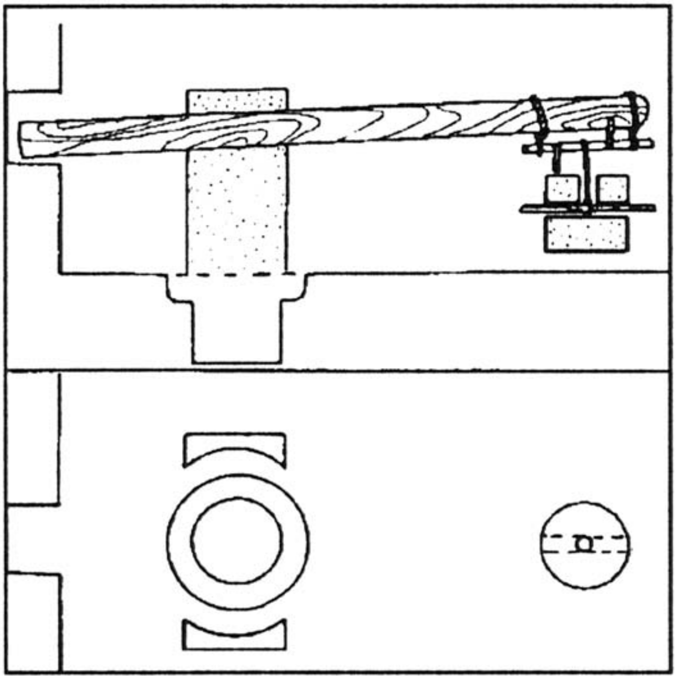

Fig. 1 Type 1 press (lever and weights) from Frankel (1999).

Type 1: Lever and Weights

The lever and *fulcrum* was one of the earliest machines that allowed man to multiply muscle effort to his advantage. The *fulcrum* of the lever press is situated at the end of the press beam, set into the stone uprights or in a rock-cut niche or other anchorage, whilst the free end was the point of applied force. The most simple lever press is the lever and weights press (Fig. 18), the use of which extends back to the Late Bronze Age in Cyprus and Syria, and to the Early Iron Age in Israel.[41] Examples of this press type still functioned in the modern eastern Mediterranean.[42] Press weights found in late antique contexts on Cyprus, at Dhiorios and Kourion, amongst other locations, suggests that a number of these early presses functioned throughout the period.[43]

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[41] Frankel (1999) 66; Hadjisavvas (1996) 130–34.

[42] Frankel (1999) 60–62.

[43] Catling (1972) 14–15; Hadjisavvas (1992) 44–45.

A long, heavy wooden beam comprised the lever. Beams varied in size, dependent upon the overall dimensions of the press. Since these components are wooden they do not survive in the archaeological record, though beams from Iron Age Israel are calculated at l. 5–6 m. At the opposite, free end of the beam, force was applied by hanging stone weights on it. Such press weights weighed 100–120 kg.[44] Weights were manufactured in many shapes and sizes; those studied on Cyprus often are conical, with a perforation at their top. A rope was fitted through this hole, allowing the weight's attachment to the press. Stacks of baskets filled with olive mash were placed at the fulcrum point, where the massive beam met the baskets. As the workers lowered the beam to the stack, the pressure thus exerted squeezed from the baskets a mixture of oil and watery lees.

Collection facilities varied in Type 1 presses. Central collection, in which the cistern that received the expressed liquid was located directly beneath the olive stack, predominated in ancient Israel.[45] The extent to which oil could be purified by such gravity systems was limited in presses that used central collection, since the heavier waste products and oil flowed into a central tank often lacking an outlet to auxiliary tanks which would have expanded processing capacity. The most impressive North Syrian type is represented by an installation at Bettir, which had a four-stage series of oil pans for purification, indicating an estate that used simple technology to eliminate labour and whose main product was high-quality oil destined for the market.[46] According to Columella (*de re rustica* 12.52.11), the oil was scooped from the vat by hand using a ladle, and then strained in pans. In some presses, such as that from the Kouris Valley, Cyprus, oil overflowed from the central vat into a lateral collection vat, and these types may be seen in abundance in Syria, where their presence indicates facilities intended to produce increased quantities of pure oil with less work.[47] Despite limited refining possibilities, central collection vats continued throughout history to be used with lever presses.

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[44] Hadjisavvas (1992) 37–38, 60.

[45] Frankel (1992) 62–64; (1997) 75–76.

[46] Callot (1984) illustrates lateral collection at Betttir, pl. 100 Sarfūd, pl. 120, Kafr Nabo, pls. 122, 123.

[47] Hadjisavvas (1992) 79.

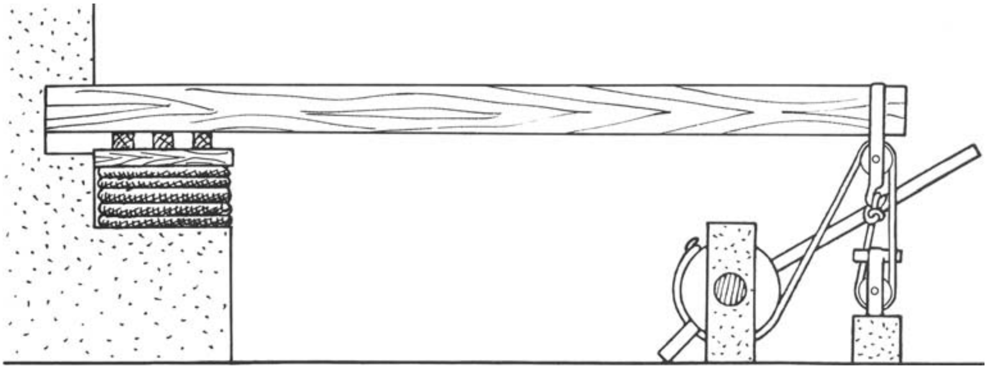

Fig. 2 Type 2 press (lever and drum press) from Frankel (1997).

Type 2: Improved Lever Press (Lever and Drum, Improved Lever and Weights)
The Type 2 press encompasses a broad category of installations that share the same basic operating principles as Type 1. However, Type 2 models integrated a number of advancements in the way that the press beam was anchored and manipulated and the point at which oil was extracted, specifically the placement of the press bed. The following examples illustrate improvements in press technology. Some presses incorporated only one feature of this technological adaptation, others displayed several.

Fig. 2 illustrates the lever and drum press, a press described by Cato.[48] A hoist acted in conjunction with a stone anchor to manipulate the beam. The fixed end of the press beam was anchored in stone uprights. Its free end was generally fitted between wooden piers, attached at the base to the *sucula*, the drum used to lower it. Workers moved the end of the beam by rotating the *sucula* using handspakes inserted into the drum. A pressing board was sometimes fitted on the press at the point where the beam settled onto the olive stack, and the olives themselves were placed on a press bed. Often the latter was incised with a *canalis rotunda* that allowed the oily conglomerate to flow more easily into the collecting vat. Examples of stones with the *canalis rotunda* are found throughout the Near East, especially in Cyprus.

Other versions of the improved lever press used weight stones, perforated similarly to those of the Type A presses, but raised and lowered by the use of levers/handspakes attached to the press beam or to the weights themselves. Hero of Alexandria described a pulley sometimes used to lift the counterweights of the Type 2 press.[49] For late antiquity, the so-called 'reverse-T' weight, indicative of the Type 2 press, was the most common counterweight found in Israel, with 65 examples recorded, while others are known from Lebanon and Cyprus.[50] The 'Semana' weight, common in North African presses, appears only rarely in the eastern Mediterranean, namely on Cyprus; here, in his reconstruction from the Kouris Valley, Hadjisavvas believed it accommodated a screw. Ethnographically studied parallels suggest, however, that the Semana type is used as a beam weight, not a screw-weight.[51]

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[48] This press type has been analysed by Brun (1986) 90–92, Drachman (1932) 50, and Frankel (1997) 74.

The slotted pier at the *fulcrum* end of the beam is also an innovation within the development of the Type 2 press. Carved into the piers, on opposing faces, are vertical slots. During operation, these slots accommodated wooden fittings upon which the press beam rested. As the height of the olive stack underwent compression, the wooden fittings were shifted, which allowed the operating height of the beam to be lowered. The beam's useful pressing motion was therefore extended, which permitted more thorough and repeated pressings to create variable grades of oil.[52]

Type 3: Lever and screw press

A major constituent of further Hellenistic technological refinement of extraction equipment was Type 3, the lever and screw press. This type advanced the method of beam manipulation through use of the screw. In the Type 3, a wooden screw was fitted into the free end of the press beam and fixed in a floor socket or, more commonly, in a stone counterweight—the screw-weight. Turning the screw lowered the beam. As White noted, the Type 3 press with floor-anchored screw often jammed as a result of torsion, since the lever descended in an arc, rather than a straight line. Hero of Alexandria provided a partial solution by incorporating on the beam a hinge mechanism.[53] The screw was threaded within a slightly mobile nut above the beam, and

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[49] Drachman (1932) 63–67; Frankel (1999) 87.
[50] Frankel (1997) 76–77.
[51] Oates (1953) 84–87.
[52] Frankel (1999) 78–79; Hadjisavvas (1992) 85–114.
[53] Frankel (1999) 107; White (1975) 231.

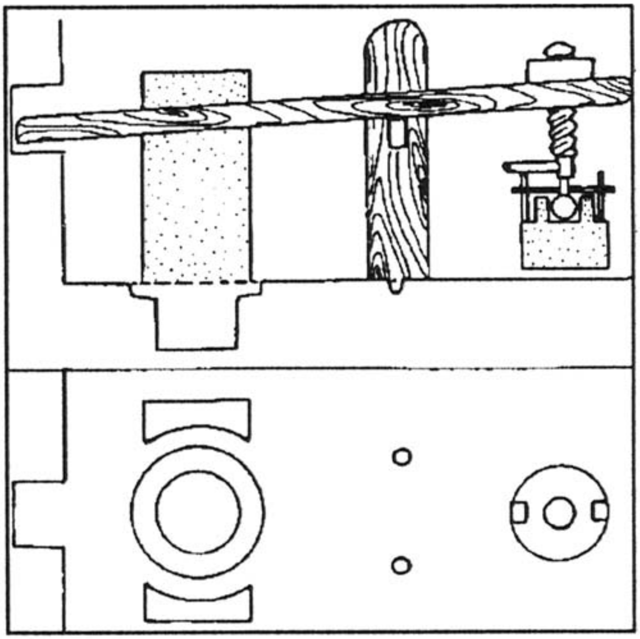

Fig. 3 Type 3 press (lever and screw) from Frankel (1999).

the wooden screw itself was somewhat flexible. Nevertheless, moving parts had to be kept well lubricated. White's claim that the counterweight, which during pressing was raised off the ground, significantly alleviated this problem, seems untrue. Wooden parts operated under significant strain: for example, the screw in a press at Bethany has warped over time. Various forms of screw-weights survive throughout the Levant, differing from one another in shape and in the way the screw was attached.[54]

The primary advantage of the lever and screw press is its ability to apply amplified steady pressure to the olive stack. This increased the speed of each pressing, not the ratio of extracted oil. As it represented a technological advancement over previous types, Type 3 required greater specialisation and more technical expertise to produce: the wooden screw is the most obvious component which demanded skilled labour. It was used throughout the western Mediterranean: screw-weight finds of the Roman period at sites like Ollioules-La Tourelle, France and

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[54] Frankel (1999) 111–21.

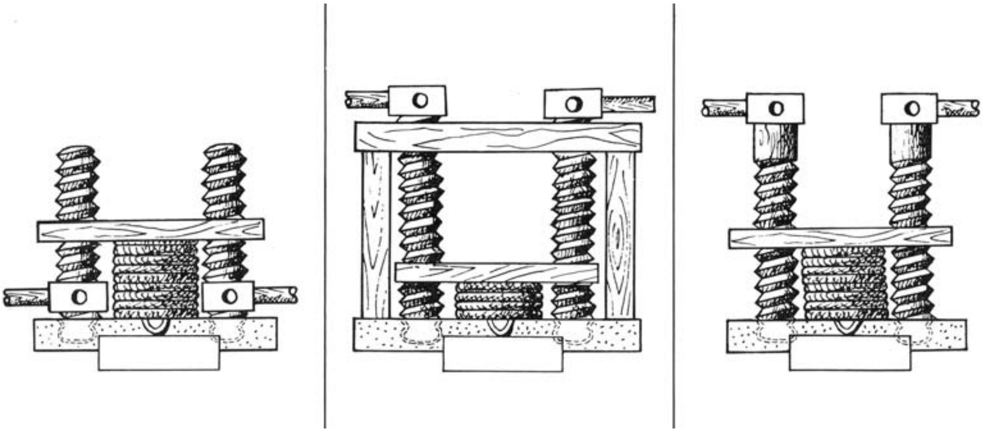

Fig. 4 Type 4 presses, from Frankel (1997).

Turrios-Berceo, Spain, raise the possibility that the screw was used in Palestine in an earlier period.[55] In Oriens, however, the widespread introduction of the screw press dates only from the Late Roman period, when the need for new presses aided its diffusion. Its spread was further helped by the fact that the screw mechanism could be fitted easily to existing lever presses.[56] Type 3 presses continued to work side-by-side with other types throughout Late Antiquity and beyond. Several late antique types were re-used in medieval contexts. This appears to be the case at Bethany, where the late antique ecclesiastical oilery operated throughout the medieval period.[57] The screw-weight at Bethany was of the 'Samaria' type (Frankel T62111) and is the sole example dating to before Late Roman times. All other known screw-weights recovered thus far belong to the Late Roman period.

Type 4: Direct-Screw Press

The removal of the beam was the next stage of press development. The result was a press type that occupied a much smaller space than traditional lever models, exerted increased force and worked more efficiently. That the Type 4 press was a later invention than Types 1–3 is known from Pliny.[58] He remarks that the press was invented 22 years before his writing, which occurred during the mid-1st c. A.D.[59] The passage describes the direct-screw model as a new invention which included smaller press frames, and a single screw pressing down from above the stack (in this case) of grapes. In the 1st c. A.D., Heron of Alexandria described direct screw types with single or double screw, although their reconstruction remains uncertain.

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[55] Brun (1986) 178–81; Pilar Pascual and Moreno Astio (1980) 200–201, fig. 3.

[56] Frankel (1999) 165.

[57] Saller (1957) 130, pls. 68–69.

[58] *H.N.* 18.74.317.

Gichon discussed finds of Early Roman pottery discovered in the 19th c. in the vicinity of direct-screw presses. However, the single excavated example of a direct-screw press is from Korazim.[60] The excavator notes, without providing specifics, that ceramic finds support a 2nd c. A.D. date.[61] Outside Korazim, however, the only dated example of this press bed type comes from the excavation at el Koursi, where it is firmly dated to the Late Roman period.[62] In Oriens, the date of the introduction of the direct screw press thus remains uncertain. As the type is largely unattested in the Early Roman period and fully entrenched by the 6th c., a wide distribution in the 4th c. seems possible.

In the late antique Levant, oil producers employed several types of direct-screw presses. Fig. 4 illustrates known variations in use from ancient to pre-industrial times. Substantial force was required to extract oil; in order to withstand the pressure, such installations required rigid wooden frames.[63] Since screw presses were almost exclusively of wood construction, only their stone beds survive. Surviving press beds could have incorporated one of a number of forms. It therefore remains difficult to determine specific Type 4 shapes common to a given region throughout Late Antiquity. In Type 4 presses, the screw applies direct pressure on the olive mash or grapes, which rested on the carved stone bed.

Many Type 4 press beds are quite small and portable. Type 4 bases are found across Israel and Cyprus; but the present published data are almost exclusively from the former. No late antique direct-screw press from Syria has been published, and only 9 of the screw press bases in Frankel's catalogue come from outside of Israel. The present, limited evidence suggests that Type 4 in Late Antiquity was used primarily in the south-east Mediterranean. As noted, the overwhelming majority of datable screw press beds found in Israel belong to the Late Roman period.[64]

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[59] Jüngst and Thielscher (1954), 108–109.

[60] Gichon (1979–80) 206–44.

[61] Yeivin (1984).

[62] Frankel (1999) cat. 1: 81.

[63] Frankel (1999) 122; White (1975) 231.

Wine Presses

The *Geoponika* (6.1) specifies that the winepress was to be built with enough space for storage of grapes before pressing, and to contain the fruit and must whilst processing. The same passage states that presses were to be plastered on all sides. This was done in order to create a clean and easily maintainable, waterproof working area. Many late antique Palestinian presses had white mosaic floors instead of plastered surfaces. Although *Geoponika* 6.1 suggests that the press was to be placed inside, extant examples in Oriens generally are open structures, outside villages and houses. Covered winepresses are known from North Syria, where installations such as those at Qirqbize were roofed. Palladius restricted his comments on winepresses to the simple treading floor, the most common type of winepress throughout antiquity. He stated (1.18) that there are two vats connected to the treading floor by earthen pipes, but otherwise offers few details.

1. Simple Treading Floors

Simple treading floors survive by the thousands in Oriens, and certainly were the most common installation for extracting grape juice. These treading floors often were the only equipment used in extracting the must from the grapes. Two or three treadings were performed in simple wineries: the first yielded superior quality wine suitable for the market and probably often sold, the second (and third) treading produced wine of lesser quality probably restricted to subsistence needs. Treading floors were used in all periods and frequently those that have survived are considered to have witnessed long cycles of use, abandonment and re-use. This is especially true in densely populated regions like Palestine, where successive settlements simply cleaned and re-utilised derelict treading floors. Most surviving treading floors are rock-cut. They often are of modest size (under 5 × 5 m) and thus suited to the agricultural endeavours of the smallholder or tenant farmer. The working surfaces of such installations varied in shape, but a common arrangement was a rectangular rock-cut floor that sloped gently into the collecting vat.

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[64] Frankel (1985) 66–71; Yeivin (1984) 66–70; Frankel (1997) 79.

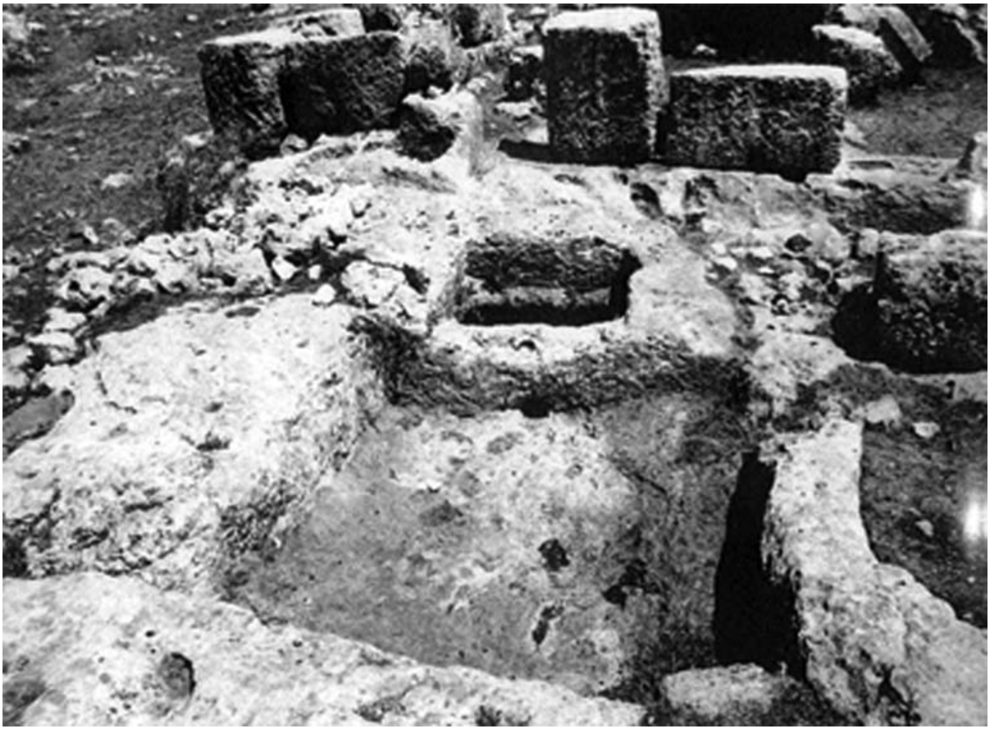

Fig. 5 Gökören winepress, from Hild and Hellenkemper (1990).

2. Improved wineries

'Improved wineries' (see above, Fig. 4) shared the sloping, flat treading surfaces of the simple press. Compartments adjacent to the treading floors are common amongst improved wineries. Large compartments contained the grapes awaiting pressing, whilst small compartments contained the spices and additives commonly used to treat wine in antiquity. Rabbinic literature mentions the 'curing' of grapes, a process called in Greek, *eliaston*, which involved sun-drying the fruit for several days before pressing to produce sweet, raisin wine. Presses discovered in Israel and fitted with large-scale compartments demonstrate this was a common practice.[65] The capture of the first must which trickled from the sun-drying grapes was accommodated by the addition of auxiliary treading floors and vats, as evidenced from wineries in the Carmel, Central Palestine and Arabia.[66]

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[65] Hirschfeld (1983) 208–11; Roll and Ayalon (1981).

Lever and screw winepresses (Type 3) were common in the eastern landscape and utilised in both wine and oil production. In regions outside Palaestina-Phoenice, the beam press appears to have remained the primary type. This seems to be the case in Syria and Cilicia, where wineries with beam niches are common. Winepresses relying on beams to exert pressure continued to be used in Palestine, as attested by sites such as Judur and Bet Hashitta, but in the provinces of Oriens screw technology was dominant.[67] As noted above, the Type 4 (direct-screw) press, often smaller than those of Type 3, required less timber to build and was easier to operate. Additionally, it could be operated in a confined area. More importantly, the screw was more efficient and potentially portable. The direct-screw winepress in wine production, like its counterpart in oil processing, was utilised primarily in Palaestina I and II, Phoenice and Arabia. Frankel recorded 175 examples of direct pressure (screw) winepresses of the late antique period in the region of the three Palestines.[68]

Direct-screw wineries often had a fixed mortise, cut into bedrock in the treading floor, or carved into a small stone block. The mortise anchors frequently incorporated a small pressing platform, and sometimes possessed a channel through which flowed the pressed liquid. The type is well depicted in the mosaics near Mt. Nebo (Arabia), at Qiriat al Mekhayyat and Qabr Hiram (Phoenice Maritima) outside Tyre.

3. Roller Installations

Another type of winepress employed in the late antique period used large, cylindrical, column-like stones (Fig. 6). Palestinian wineries incorporating stone rollers are limited to the Galilee and the Carmel, both centres of intensive late antique agricultural activity and wine production. 16 sites are known which utilise slotted stone rollers, whilst another type, the simple roller without grooves for inserting hand levers, occurs on six sites in Israel.[69] These installations are a ubiquitous feature in North Syria and generally are interpreted as oil presses.[70] A full

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[66] Frankel (1999) cat. 2: T803.

[67] Frankel (1999) 146.

[68] Frankel (1999) 147.

[69] Frankel (1999) 146.

[70] Callot (1984) *passim*.

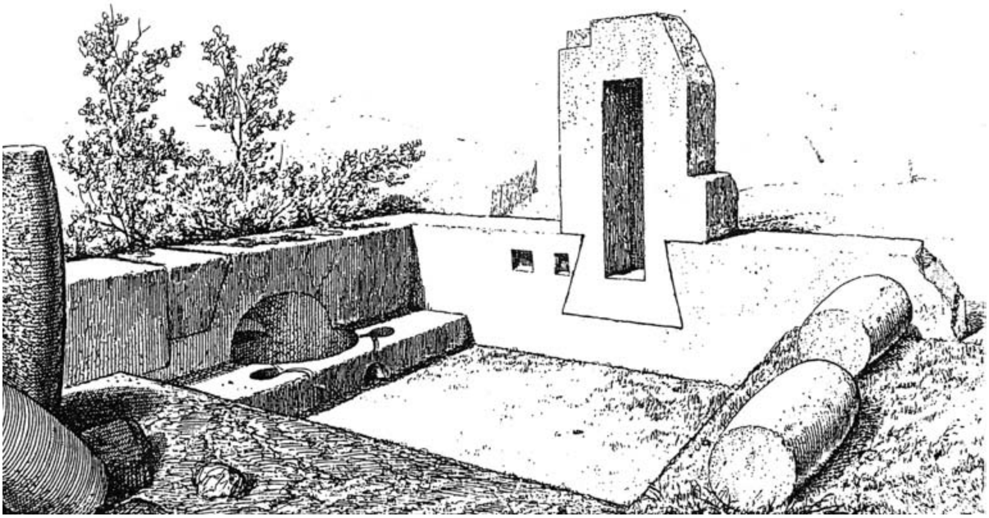

Fig. 6 North Syrian roller press, from De Vogüé (1865) 77.

assessment of these sites is needed in order to positively identify their use. At present, however, it seems that the roller installations seem to be a solution adopted in Oriens to encourage the rapid processing of grape products.

Technology and the Late Antique Economy

The technological shift in winepresses discernible in Late Roman Palestine, from simple wineries to more elaborate installations equipped with screw technology, therefore parallels developments in oil pressing. The importance of screw installations for assessing the nature of the late antique economy is three-fold. Such installations enabled one to create various grades of wine beyond those generally possible when utilising simple treading floors alone. Perhaps more importantly, they indicate a desire to process grapes quickly and on a larger scale than those only involving small treading floors, which served primarily for subsistence purposes. Both argue for production geared toward the market. Finally, the use of screw technology within the wine and oil presses in the ancient Levant indicates a sizeable number of farmers aware of an existing technology that had hitherto been apparently rather neglected, and that they were willing to expend capital on its implementation. The adoption of this technology was particularly acute in those areas where the greatest surpluses of wine and olive oil were produced for export. The balance of the evidence therefore suggests that the decision to incorporate the re-vivified technology was a conscious one, a relatively rapid one, and based on a series of factors, but primarily upon the demand for eastern agricultural commodities.

We therefore possess strong indications that economic conditions could, and did, sometimes spawn extensive technological change throughout the countryside. This was neither a limited, nor a superficial change: despite the fact that screw presses had been known from at least the Hellenistic period, their apparent failure to spread rapidly is not entirely surprising given the conservative nature of pre-industrial societies and the complexity of technological change. In the case of the Levantine coast and the relatively swift spread of the technology during Late Antiquity, we may surmise that a host of complex factors combined fortuitously to push certain technologies beyond their previous development. Among the few factors that I can suggest are the following: the demographic increase that is detectable in the settlement patterns of the Levant at this time fostered greater competition in land and in the market; the associated rise in the urban population engendered an expansion of the urban marketplace, while simultaneously creating a larger pool of workers whose means of subsistence was specialised trades of various kinds; with the rise in population came an attendant increase in the number of skilled workers as the economy became more connected and sophisticated.

Egyptian estates, for example, reached a peak of managerial complexity, labour organisation, and technology in the 4th–7th centuries A.D.[71] During the same period, they continued to expand and relied substantially on artificial watering. While the huge tracts colonised by the Ptolemaic kings were not repeated during Late Antiquity, there was, nevertheless, substantial development and re-use in the agricultural landscape. Dry land needed water in order to bloom, and the great estates provided that water by means of technology, primarily through bucket chains (*qadus*) utilising *saqiya*-driven wheels. The building and maintenance of these water installations shows a deep commitment to technology and to the men required to make them function, as the machines are not simple; each one required hundreds of individual parts and demanded frequent maintenance.[72]

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[71] Banaji (2001).

Irrigation Technology and the Eastern Wine and Oil Trade

It is intriguing that this sophistication in land management within Egypt finds sharp parallels in the diocese of Oriens—comprising the eastern Mediterranean seaboard from Isauria to Gaza and inland regions. In the landscape of Oriens, there were widespread and intensive efforts to diminish risk by harnessing existing water sources to their fullest. In addition, there were substantial efforts aimed at increasing the availability of water to plots where production was to be marketed. This trend may be seen in the 4th–7th c. appearance of ceramic evidence indicative of *saqiya*-driven *qadus* water lifting machines. The *saqiya* (Arabic 'irrigator') is often used to denote the entire water-moving machine, whether it be a *saqiya*-driven waterwheel (*noria*) or a chain-of-pots (*qadus*). The *saqiya* is, in fact, the gearing mechanism which allows energy applied on the horizontal (rotary) to be converted to vertical motion; a kind of rack and pinion device in which the rack is the horizontal component and the pinion is the vertical. Thus, an oxen treading in a circular floor may be yoked to a wheel turning parallel to the ground. The horizontal wheel is toothed, and these teeth interlock with the vertical, that in turn drove a wheel, or lifted a chain-of-pots.

Watson considered the *saqiya* to be a development of the Islamic period, but this is clearly incorrect.[73] It probably belongs to the Hellenistic milieu, as argued by Lewis, who believes that the archaeological data supports a 3rd c. B.C. date for the creation of the *saqiya*-driven *noria*. It is not until the Roman period in Egypt that we can discern widespread use of the *saqiya*, which was certainly prevalent there in the 4th c.[74] Ayalon's survey of *qadus* jars found in Israel can be substantially supplemented, and by my current tally, there is evidence for 46 sites where *qadus* jars and *saqiyas* were probably in operation during the late antique period.[75]

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[72] Tacoma (1998).

[73] Watson (1983) 154.

[74] Hill (1996) 771; Oleson (1984) 373. There has been no systematic effort to collect the evidence of the *papyri* and archaeological material. The former present challenges in discerning the precise type of machinery in use.

[75] Ayalon *et al.* (2000); Decker (2001) appendix 3.

The *saqiya* has been credited with a large share in the so-called 'Islamic Agricultural Revolution' that swept across the Mediterranean during the first centuries of Muslim rule. Allowing as it did an output that was greater than that possible from cruder machinery such as the *shaduf*, or Archimedes' screw, there is little doubt that the *saqiya* offered hitherto unobtainable productivity in the realm of irrigated agriculture. Isolated wells, which had, until the machine's introduction, been limited to watering by hand, were transformed into viable irrigation points. *Saqiya*-driven wheels and *qadus* chains could lift water to a height of 20 m, beyond that possible for simple manual exploitation. A single machine could irrigate from 2–13 ha, perhaps 100 times larger than the area potentially watered by a single *shaduf*.[76] But *saqiyas* were not cheap: they were comprised of hundreds of wooden parts and required animals to power them—camels, mules or oxen. The machinery thus represents significant capital outlay and access to the technical expertise—skilled carpenters with working knowledge of the machine's geometry. There is little doubt, however, that the machine's impact was felt deeply in dry areas. Where hitherto there existed no infrastructure to support irrigation, a well could be sunk and the *saqiya*-driven *qadus* emplaced. The volume of water that could thereby be delivered to a concentrated area was substantial. If the well was private, and many were, there was no need to share the water with one's fellow farmers, as was the case in large-scale irrigation works that were state or community projects, especially in Palestine, where landholding was almost certainly more fragmented and less centrally-managed than that of the great houses of Egypt. Not coincidentally, by Late Antiquity, the vineyards of Egypt used screw presses extensively.[77]

The integration of *saqiya* installations into the vineyards of Palestine is certain. At Ramat Hanadiv, where the late antique complex was engaged in large-scale wine production, finds of *qadus* jars provide evidence for a *saqiya* during this period there.[78] At Akhziv, *qadus* jar fragments were found washed into a winepress in the vineyard the machine no doubt irrigated.[79] Likewise, wine and oil presses were the major economic features discovered at Zur Natan, where more *qadus* fragments indicate that the vineyards and oliveyards there were also irrigated with animal-driven machinery.[80] These examples argue for a new integration within the agricultural landscape of Syria-Palestine, with farmers willing to make significant capital investments in response to prevailing conditions.

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[76] A maximum figure; the ranges of both machines varied, but my calculations suggest that the *saqiya* could irrigated 16 to 100 times the area of a *shaduf*.

[77] Rodziewicz (1998).

[78] Calderon (2000) pl. XXV, 73–75.

[79] Syon (1998) 92 fig, 12 nos. 17–19.

We can do little other than assume rational motives for this activity, that is, that the wine producers expected to receive a return on their investment. The *saqiya* had the benefit of appealing to the naturally conservative landed classes: it was a proven instrument of land enhancement, apparently imported from nearby Egypt, where it had probably been in operation for centuries. Like any irrigation device, it minimalised risk by safeguarding against crop failure. Drought was frequent in the Mediterranean, and any way that one could combat the capricious nature of the elements to ensure a stable return appealed to a society, which, first and foremost, sought to reduce risk. Ultimately, however, the aim of watering a vineyard is not merely to ensure a steady return, but to increase yields. Vines under irrigation offer increased berry size and larger returns, and in the sellers' market of Late Antiquity, the extra production would have found a ready outlet in trading centres around the Mediterranean. The *saqiyas* that delivered irrigation to the vineyards of Palestine turned water into wine.

In Late Antiquity, there are a number of detectable phenomena closely related to one another within the milieu of agricultural technology and economy. The rise of the regional transport jar, and perhaps early efforts at standardisation, are presented by the case of LR 1. The distribution, frequency and raw numbers of the amphorae themselves demonstrate the breadth and depth of the trade in eastern agricultural commodities. This substantial trade has left traces on the ground in modern Israel, in particular, where the remains of catalogued late antique presses approach 1,000 in number. Many of these presses were built in the late antique period and utilised screw technology. Although not a new technology, the case of the wine presses of Late Antiquity, in use from Egypt to Syria and beyond, were indicative of a brief period of market integration, capital investment, and technological change that accompanied the end of Late Roman rule in the East.

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[80] Matthews *et al.* (1990).

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WINE-MAKING AFTER PLINY: VITICULTURE AND FARMING TECHNOLOGY IN LATE ANTIQUE ITALY

Jeremy Rossiter

Abstract

This article uses a range of archaeological and literary evidence to reconstruct the state of wine-making technology and the organization of the wine trade in late antique Italy. Continuity of commercial wine production in many regions of Italy and continuing trade in Italian wines both inside and outside Italy is clear up to the Lombard invasions. Technological continuity with the earlier Roman period is strong, with horizontal lever presses, using stone weights, remaining in common use. There is little evidence for technological innovation during this period. Vertical and direct screw presses, which become common in the East at this time, are rarely found at farms in late antique Italy.

Modern accounts of Roman wine and wine-making technology have tended to pay little attention to the centuries after Pliny.[1] There are two good reasons for this: firstly, nearly all the major Latin agronomists who provide technical accounts of wine-making (i.e. Cato, Varro and Columella) wrote earlier than Pliny; secondly, much of the archaeological evidence for wine-making comes from sites in and around Pompeii and dates to before A.D. 79. The coincidence of the eruption of Vesuvius and Pliny's death provides a convenient *terminus ante quem* for both the textual and archaeological material. Moreover, Pliny's description (*Nat. Hist* 18. 317) of the various types of wine presses in use in his day, has generally been taken as a definitive statement of how far the Romans progressed in their attempts to bring greater efficiency to the processes of wine-making. What happened in the centuries after Pliny has been largely ignored, perhaps because of a tacit assumption that Roman

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[1] For accounts of Roman wine-making, see: White (1970); Rossiter (1981); Tchernia (1986); Fleming (2001); Brun (2003) 49–83, (2004) 7–60; Thurmond (2006) 111–164. Most of these works, with the exception of Brun (2003; 2004), make little use of late antique material.

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farming technology made little, if any, progress after Pliny's time, so therefore there is little worth adding to the information he provides.[2]

While the emphasis on the Early Roman period is understandable, it has also led to an unnecessarily 'periodised' view of Roman farming practice. In reality, there exists a good deal of evidence, both textual and material, informing us about wine-making in Italy in the centuries after Pliny. That this may not reveal significant technological 'progress' is not a reason to ignore it. There is much we can learn from this later evidence about the methods of wine-making which continued in use and about the range of equipment which was employed at late antique wineries. The evidence includes written accounts, legal documents and inscriptions, as well as material from excavated farm sites and representations of wine-making in art.[3] In this paper I will re-assess this evidence with the aim of answering the following questions: firstly, what can we learn about the processes used in wine-making in late antique Italy: does the evidence suggest any technological progress in wine-making since Pliny; secondly, what kind of equipment was employed and what terms were used to identify it; and thirdly, how does the late antique evidence for wine-making technology fit into the broader picture of wine production in Italy in the centuries which separate the Late Roman from the Early Medieval worlds?[4]

Sources for Late Antique Wine-Making

The written sources for late antique wine-making include one technical and numerous non-technical writings. The first is the farming manual (*Opus Agriculturae*) of Palladius. Both the date and geographical setting of his work are controversial, but for the purposes of this paper I will accept Martin's date of *ca.* A.D. 470 for the composition of the work and take what Palladius says as being relevant to farming conditions in Italy in the 5th c.[5] His text partly derives from the earlier technical treatise of Faventinus (*Artis Architectonicae Privatis Usibus Adbreviatus Liber*), a work usually dated to the late 3rd c. A.D.[6] Both Palladius and Faventinus owe much to Vitruvius. However, both authors introduce new material into their works, thereby making them more relevant to the times in which they wrote.

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[2] On the poor representation of Late Antiquity in studies of Roman wine-making, see Rossiter (1998) 598.

[3] Brun (2003) 185–222.

[4] In accordance with the theme of this book, Late Antiquity is here defined as the period from Diocletian to the Lombard invasions (late 3rd to late 6th centuries A.D.). I will deal mainly with evidence from Italy, or evidence which can be considered relevant to conditions in Italy. It may at times be useful to introduce material from outside this country and from the centuries before or after Late Antiquity, but I will do this only if it seems useful to the discussion.

The many non-technical texts which shed light on the processes of late antique wine-making do so in a more random and incidental manner. As we shall see, references to wine-making in 4th–7th c. sources are plentiful, but most are brief and rarely represent the primary interest of the writer. They usually appear as anecdotal or incidental comments in a variety of literary contexts: in biographies, in letters, in sermons, and in biblical commentaries. Of particular interest are the writings of the Late Roman orator, Quintus Aurelius Symmachus. Symmachus' surviving correspondence contains numerous letters written from and about the Late Roman countryside. From these we get more than a casual glimpse of life, and labour, at the many farms and estates owned by his family in Italy.[7]

The archaeological sources for late antique wine-making in Italy present unique problems. As we have noted, nearly all the major studies of wine-making and farming technology in Roman Italy have depended heavily on the evidence provided by excavations in the *Ager Pompeianus*, where numerous farms and wineries have been unearthed over the past 200 years. The best new evidence comes again from this same region.[8] What is much more difficult to find is evidence for wine-making at farm sites known to have been functioning, or better still, newly built, in the period of Late Antiquity. Obviously, we will need to turn our attention away from Pompeii and look for possible traces of late antique occupation at farm sites elsewhere in Italy. This may yield clues to the kind of processing equipment used in Late Antiquity and provide some material evidence with which the more plentiful textual evidence can be compared.

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[5] Martin (1975) xvi; Vera (1999) 284; Brun (2003) 192.

[6] Plommer (1973) 2; Cam (2001) xiii–xvii.

[7] The standard text of Symmachus is that by Otto Seeck: *Q. Aurelii Symmachi Quae Supersunt* (MGH, 6.1) (Berlin 1883). See also: J.-P. Callu (1972–2002). On Symmachus' villas: Vera (1986).

[8] See, for example, the new studies of *villae rusticae* by De Caro (1996) and De Spagnolis (2001).

Some of the best documentation for wine-making processes in Late Antiquity can be found in art. Partly because of the powerful symbolism of the vine in Christian art, images of vines, vineyards and wine-making became increasingly popular in Late Roman and Medieval art. As a result, numerous representations survive—in mosaic, in relief sculpture, and in painting—of scenes showing the various stages of production. These provide valuable clues to the processes and equipment employed.

The Processes of late antique Wine-Making

The processes of wine-making are spelled out by a number of late antique writers. In most cases these are 'layman's' accounts in which the authors do not show particular interest in technical details. A typical account occurs in a work attributed to Zeno of Verona (mid-4th c.). Zeno describes the process of wine-making from harvesting to fermentation:[9]

> When the time of the vintage arrives, the grapes everywhere are gathered in proper fashion and after they have been trodden by the feet of the labourers in the winery, they are pressed by the beam (*praelum*) and squeezed tightly between two boards (*tabulae*) until all the sweet juice is extracted. And so the precious juice is not only drunk by the treaders, but is brought into the landlord's wine store (*cella vinaria*) where it is left to improve with age.

Zeno's account echoes earlier Roman directives on how to process wine. The main stages of production are outlined in familiar fashion: the harvesting of the grapes, the initial treading of the fruit, the secondary pressing of the trodden pulp, and the transfer of the grape juice into the wine store for fermentation. There is, of course, a lot missing from this account: we are not told where the treading takes place, nor what kind of press mechanism is involved (although there are hints present, see below), nor exactly how the extracted liquid is transferred to the wine store. One unusual detail which Zeno provides is the mention of the two boards used to contain the grape pulp under the press. Similar press boards are mentioned by Cato, who calls them *orbes*, but not by any other agricultural writer.[10]

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[9] Zeno of Verona *Tractatus* 2.27.2 (*In Isaiam VI* = *PL* 11.469A): *at ubi vindemiae venerit tempus decore dissipato passim uva detrahitur, in torcularique operariorum pedibus subiecta calcatur, prelo premitur, duabus tabulis vehementer urgetur, donec omnis dulcedo medullitus exigatur. sicque pretiosum fluentum a suis calcatoribus et bibitur et patris familias cellis vinariis infertur, ut melius veterescando reddatur.*

Zeno's description of wine-making can be compared to another, somewhat more selective account given by Pope Gregory (6th c.). Gregory is describing a miracle performed by Saint Boniface of Ferentina:[11]

> Then the Saint entered the vineyard and having gathered the bunches of grapes took them to the treading floor (*calcatorium*)...When only a trickle of juice flowed from these bunches, the Saint started to scoop this up with his own hands in a small vessel (*vas*) and to divide it, with a blessing, among all the jars (*dolia*) and containers (*vasa*) which had been prepared, so that all the vessels (*vascula*) seemed barely filled from the same wine.

Gregory goes on to relate how the small quantity of wine deposited in the jars miraculously increased until the entire wine-store (*apotheca*) almost flooded with the amount of wine produced. There are obvious biblical echoes present: e.g., the miracle of the feeding of the 5,000 and the wedding feast at Cana. No mention is made of a wine press or of the pressing of grapes. But this is not surprising: what interests Gregory is the product of the treading, the 'new wine', produced under the Saint's supervision, and the way it is miraculously transformed in quantity.

In addition to these two fairly detailed accounts of wine-making, more abbreviated descriptions can be found in several other late antique sources. Symmachus, for example, writing to Marinianus, mentions both the treading and the pressing of grapes during the autumn vintage at one of his estates near Rome.[12] This is possibly the same estate as that mentioned by Macrobius in the Saturnalia when the elder Symmachus says:

> I was recently at my villa at Tusculum at the time of the annual grape harvest. I watched my slaves, together with the farm hands, drinking

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[10] Cato *Agr.* 18.9; Drachmann (1938).

[11] Greg. *Dial.* 9 (= *PL* 77, col. 189C): *tunc vir Dei vineam ingressus racemos collegit, ad calcatorium detulit...cumque ex iisdem racemis parum aliquid vini deflueret, coepit hoc vir Dei suis manibus in parvo vase suscipere, et per cuncta dolia omniaque vasa quae parata fuerant, pro benedictione dividere, ut ex eodem vino omnia vascula vix infusa viderentur.*

[12] Symmachus *Ep.* 3.23.1: *nam postquam doliis nova vina commisimus, quae calce et prelo subacta fluxerunt.*

> the juice either from the press or flowing from the floor and not being affected in any way.[13]

Elsewhere, Macrobius alludes to the storage of wine in variously named vessels (*dolia, vasa vini*).[14] Other late antique texts which refer to wine-making do so in even more contracted language. This may simply involve mention of a treading floor (*calcatorium*),[15] or of a wine-press (*torcularium, prelum*),[16] or of sunken jars (*dolia defossa*) used for fermentation.[17]

Two 4th c. mosaics from Italy show wine-making scenes illustrating some of the processes outlined above. One of these occurs on a pavement found in the Late Roman villa at Piazza Armerina (fig. 1).[18] Although incomplete, the mosaic shows several of the key production stages. At the left, a labourer brings baskets of grapes to the press-room; in the centre, a group of three labourers is at work treading the grapes; above them the massive press-beam itself, supported at one end by two upright timbers (*arbores*), is visible. The round boards (Zeno's *tabulae*) between which the pulp was squeezed are also shown.

The second is a ceiling mosaic, part of the decoration of the 4th c. Mausoleum of Constantia in Rome. The scene of wine-making shown here (fig. 2) is more selective. Like Pope Gregory's written account of the process, the mosaic focuses mainly on the treading of the grapes. We see a group of workers trampling the grapes on a raised, and roofed, treading-floor and the juice flowing directly from here into sunken *dolia* placed around the side. There is nothing to suggest a press or even an intermediate vat between the treading-floor and the *dolia*. A strikingly similar scene occurs on a porphyry sarcophagus ('Constantia's

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[13] Macrob. *Sat.* 7.7.14: *nuper in Tusculano meo fui, cum vindemiales fructus pro annua sollemnitate legerentur. Erat videre permixtos rusticis servos haurire vel de expresso vel de sponte fluente mustum nec tamen ebrietate capi.*

[14] Macrob. *Sat.* 7.12.14–15: *unde agricolae dolia non contenti sub tecto reposuisse defodiunt removentes in quantum fieri potest a vino aeris contagionem a quo tam manifeste laeditur ut vix se tueatur in vase pleno et ideo aeri minus parvio.*

[15] *calcatorium*: Serv. *Comm. in Georg.* 2.242: *prela autem trabes sunt quibus uva iam calcata premitur.*

[16] *torcularium*: Rufinus (4th c. bishop of Aquileia), *Comm. in Psalm. LV*; Petrus Chrysologus (5th c. bishop of Ravenna), *Serm.* 31, 122; Cassiod. *Exp. in Psalm. VIII*; Liutprand (10th c. bishop of Cremona) *Hist.* 6.

[17] *dolia defossa* are listed among the *instrumenta torcularii* given at *Digest* 33.7.8. pr.

[18] Balmelle and Brun (2005) 909–10; Brun (2003) 214–15. Carandini, Ricci and de Vos (1982) 306–309, plate 46.

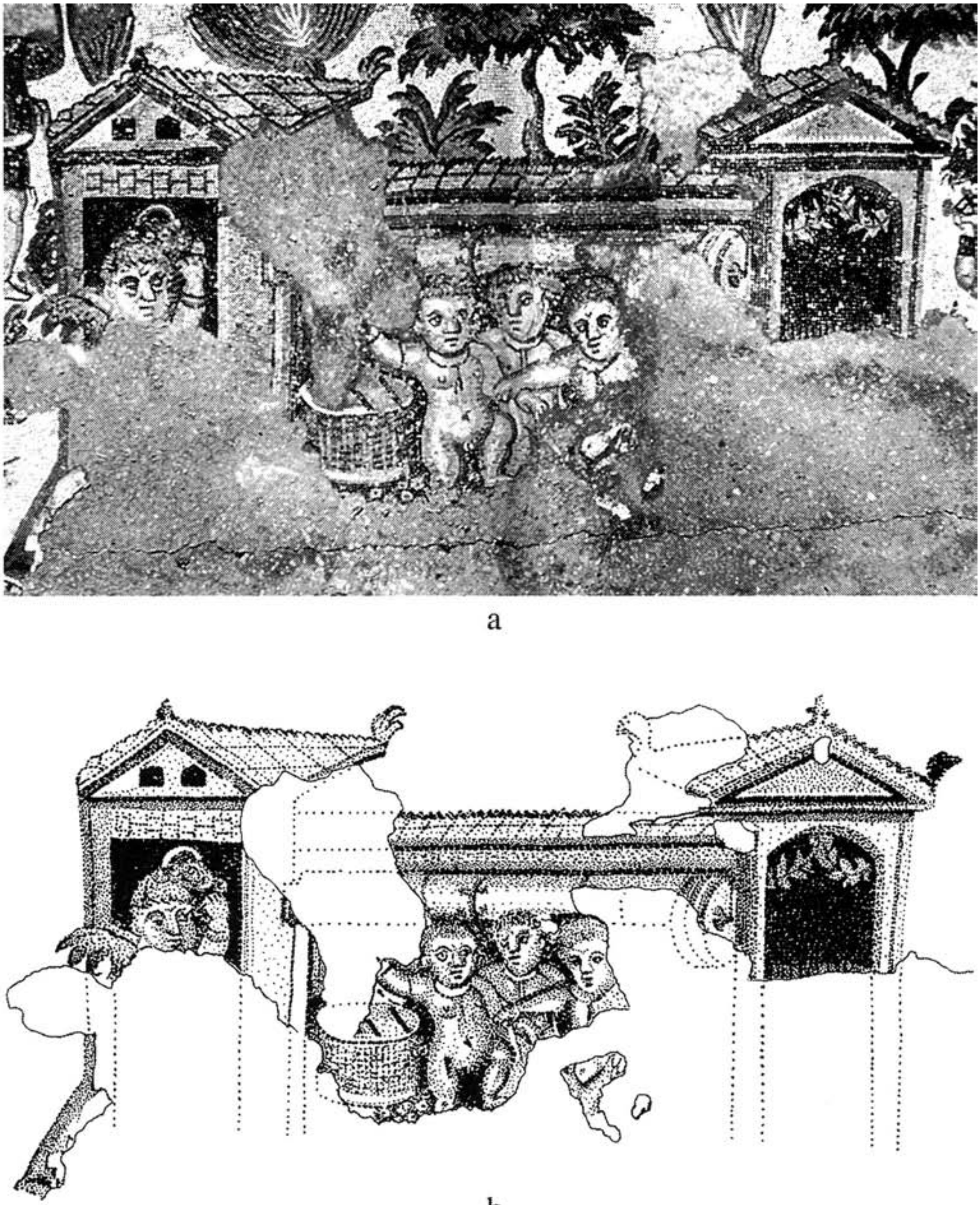

Fig. 1 Wine-making scene on a mosaic from the Late Roman villa at Piazza Armerina, Sicily (4th c. A.D.), from Balmelle and Brun (2005).

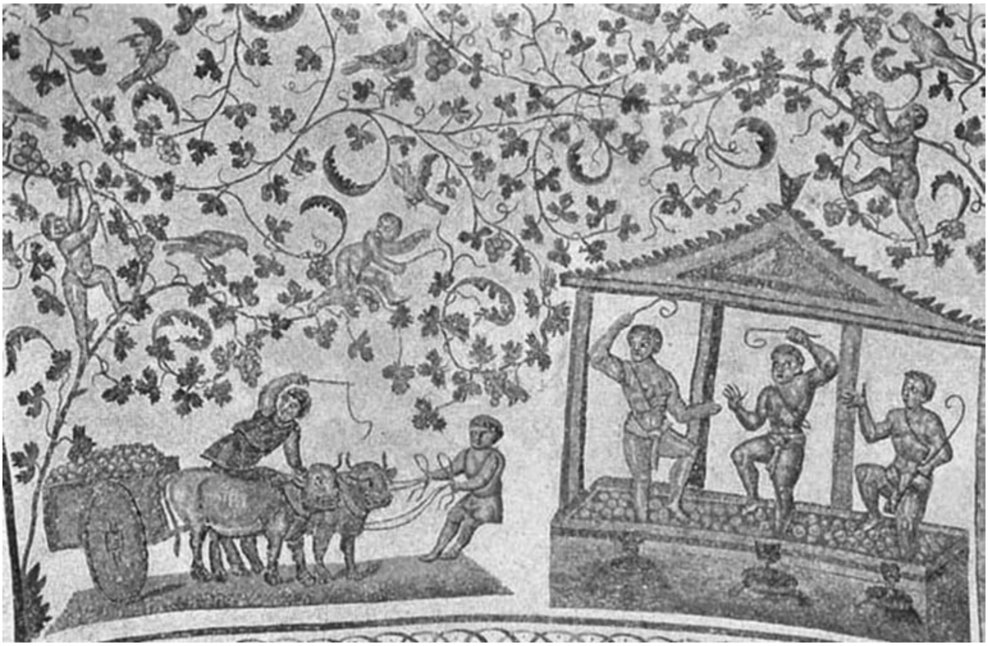

Fig. 2 Wine-making scene on a mosaic from the Mausoleum of Constantia, Rome (4th c. A.D.).

sarcophagus') from the same mausoleum, now in the Vatican Museum (fig. 3). This shows a group of 'Cupids' treading grapes on a raised treading-floor, from which the extracted juice gushes through a lion-head spout into a series of four free-standing *dolia*.

Like Gregory's account of the miracle performed by Boniface, the two Christian images focus exclusively on the treading stage of the wine-making process. It was, of course, the juice from the initial treading of the grapes which was always considered to produce the purest and best quality wine. For a true Christian, the flow of this 'first fruit' from the treading platform into the empty jars and its subsequent transformation into wine symbolised the spiritual journey of the deceased from this world to the Christian afterlife.

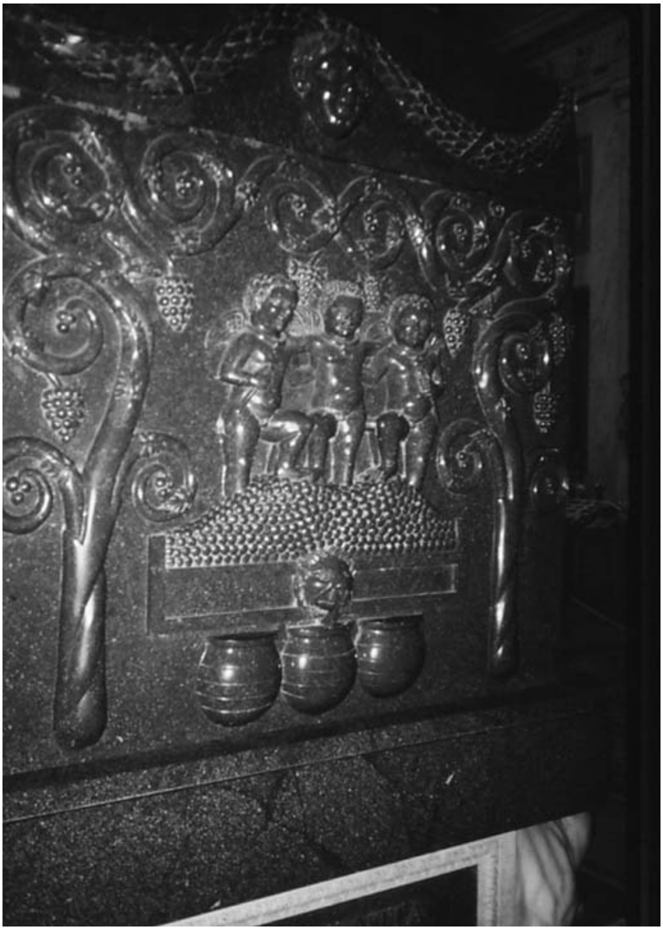

Fig. 3 Wine-making scene on the sarcophagus of Constantia, in the Vatican Museum (4th c. A.D.).

The Equipment of a late antique Winery

In the Digest, a partial list of the equipment (*instrumentum*) belonging to an Italian winery is given.[19] The list in origin dates to the 2nd c. A.D., but its inclusion in the 6th c. *Digest* suggests that its content was still considered relevant in Late Antiquity. It includes the following items: a press-beam (*praelum*), a winch (*sucula*), levels (?) (*regulae*), a drum (*tympanum*), and screws (*cochleae*). These items represent some of the portable contents of the winery. More specifically, they are all components of the actual press, or presses, in operation inside the plant. It is possible (though unlikely) that they are all parts of the same press. If this was the case, we would be dealing with an unusually hybrid form of press—somewhere between Cato's lever-and-winch press and Pliny's lever-and-screw press—for which there is no corroborating evidence.[20] The list more likely refers to the equipment of more than just one single press. The writer makes it clear that the screw was used to raise the press-beam. What is unclear is what the winch and drum were used for. Were they a mechanism for lowering the press? Or do they belong to another press, or to an altogether separate device?

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[19] *Dig.* 19.2.19.2: *et praelum at suculam et regulas et tympanum et cocleas quibus relevatur praelum dominum parare oportere*. On this passage, see B. Frier (1979).

A few late antique texts provide valuable, if not very technical, clues to the mechanical workings of wine presses. The description of wine-making given by Zeno includes the following details:

> The juice [of the grapes] is squeezed out by the enormous weight of the press beam (*ultimo preli pondere*) and by the two boards (*tabulis*)[21]

The use of the word *pondere* here implies that the press which Zeno had in mind is one where the press beam is lowered by a heavy weight suspended below the beam. There can be little doubt that this is a lever-and-screw press of the kind described by Pliny, in which the press beam is lowered by means of a stone weight (or weights) attached to the bottom of a vertical wooden screw.[22]

Cassiodorus alludes to a similar mechanism in a passage in the mid-6th c. *Expositio Psalmorum*, where he gives a brief explanation of the term *torcular*:

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[20] See Rossiter and Haldenby (1989). I am now less convinced by my earlier attempt to reconcile the evidence of the *Digest* with the excavated remains of the wine-press found in Pompeii Insula II.5. However, I still maintain that the press remains found in Insula II.5 do not fit the Catonian lever-and-winch model precisely. The main problem is the function of the square socket located below the press-beam. This cannot have been intended for access to the press substructures—it is simply too small. It must rather have been linked to the operation of the press-beam above, but how is not clear.

[21] Zeno of Verona *Tractatus* 2.27.2 (*In Isaiam VI = PL* 11, col. 471A): *succus earum in ultimo preli pondere duabusque tabulis exsiccatur*.

[22] Drachmann (1932) 50–121; White (1975) 230–31.

> A *torcular* is where grapes, pressed by many weights, with their stubborn seeds crushed and their skins made empty, pour out the sweetest wines.[23]

Again, the key words here are 'pressed by many weights' (*multis ponderibus pressae*). What Cassiodorus must be referring to are the stone weights attached to the bottom of the vertical wooden screw by which the press beam was raised and lowered.

The written sources can be supplemented by a small amount of evidence from late antique art. We have already noted the depiction of a wine-press on a mosaic pavement from the Late Roman villa at Piazza Armerina (fig. 1). Enough survives of this image to show clearly that it was a lever press. The appearance of a looped cable at the far end of the press-beam suggests that what is being illustrated here is a Catonian-type lever-and-winch press.[24] Certainly there is nothing in the image to suggest the use of a screw.

The press shown on the mosaic at Piazza Armerina can be compared to another image of a wine-press which appears on a fragment of a sarcophagus found at Aquileia (fig. 4).[25] The fragment is dated to the 3rd c. A.D. It shows two labourers turning the handles of a large vertical screw which, at the top, is attached to a cross-beam. As J.-P. Brun has suggested, this almost certainly illustrates a lever-and-screw press of the kind described by Pliny. Pliny implies that by the mid-1st c. A.D. such presses were commonplace in Italy.

Taking all this evidence together, the picture that emerges is of a diverse pressing technology. It would appear that presses of various different types—including both lever-and-winch presses and lever-and-screw presses—could be found in use at farms in late antique Italy. Two factors would no doubt have affected the type of press used: one, the condition of old pressing equipment (Was it still in serviceable condition? Was it cheaper to repair it or to replace it?); and the other, the cost of buying new equipment (Was a winch mechanism cheaper than a screw mechanism?).

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[23] Cassiod. *Exp. in Psalm. VIII* (= PL 70.73): *torcular vero est ubi multis ponderibus pressae uvae durissimis giartis comminutis follibusque vacuatis dulcissima vina profundunt.*

[24] Brun (2003) 215. Cato *Agr.* 63.1 calls the ropes used to lift the press-beam the *funes torculi.*

[25] Brun (2003) 215–16; Santa Maria Scrinari (1972) 122, no. 356.

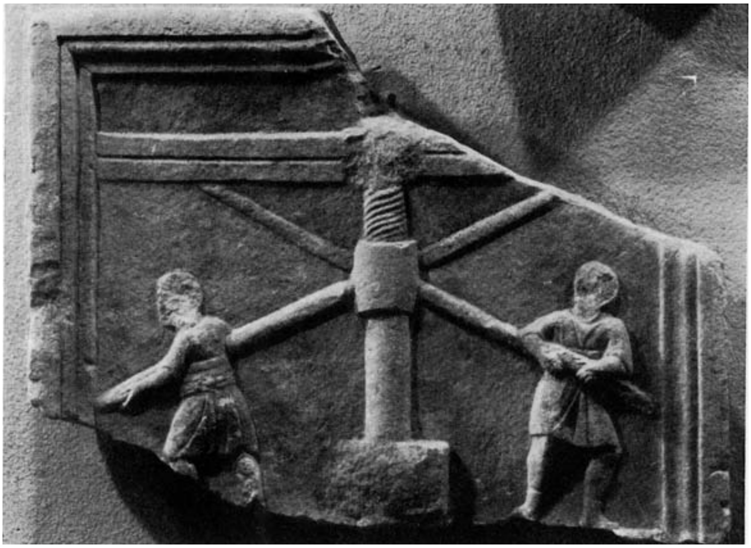

Fig. 4 Wine press depicted on a sarcophagus from Aquileia (3rd c. A.D.), from Santa Maria Scrinari (1972).

The winery would also contain a certain amount of non-portable equipment.[26] We have already noted some of this fixed apparatus. It included such things as tanks (*lacus*), pipes (*canales*) and fermentation jars (*dolia defossa*).

The Layout of a Late Antique Winery

The only late antique writer who provides a detailed account of the physical arrangements of a winery (*cella vinaria*) is Palladius. At 1.18 of the *Opus Agriculturae* we find a tantalising directive for the construction of a purpose built winery.[27] It is worth giving Palladius' text in full:

> [The winery should be arranged] so that, like a basilica, it has the treading floor at a higher level with access to it by means of three or four steps built between two sunken vats designed to catch the wine. From these vats mortar conduits or terracotta pipes should run around the edge of

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[26] A long list of the portable and non-portable *instrumenta* belonging to a Roman winery is given by Cato (*Agr.* 12–13); cf. *Dig.* 33.6.3.1 on the 'non-portable' nature of *dolia defossa*.

[27] For commentaries, see Plommer (1973) 8–11; Martin (1976) 126–27.

> the walls and feed the wine, by means of attached funnels, into the jars embedded along the bottom of the wall. If the quantity of wine produced is too large [for these jars], the middle of the room may be assigned for barrels which, in order not to impede movement, can either be placed on higher racks or put above the embedded jars, allowing a fairly good distance between each so that, if necessary, there is room for the person in charge of the wine-making to move around. If the central part of the building is indeed used for barrels, this area, like the treading floor, should be reinforced with low buffers and a concrete pavement so that even if, unnoticed, a barrel leaks, the wine which escapes will be caught in the vat and not wasted.

Palladius also recommends that the processed wine be stored in a cool and isolated location 'far from the baths, the animal stalls, the furnace, or the garbage dumps'.[28]

Palladius' 'design for a winery' has attracted a good deal of attention. A reconstruction by Plommer (fig. 5) is in part plausible but not without problems.[29] There is no reason, for example, to suppose that the building terminated in an apse. Palladius' comment that the treading floor should be at a higher level 'like a basilica' does not imply that the whole building had the form of a church. His point is that the treading floor looks somewhat like a raised tribunal, something which would be a common sight in a 5th c. courtroom. Plommer is also wrong in making the *dolia* which receive the wine from the treading floor free-standing; these should be *dolia defossa*, placed inside, not outside, the *cella vinaria.*

Attempts to reconstruct Palladius' winery are never going to be very satisfactory; there is simply too much which he omits from his text. What is more useful perhaps, is to compare his description with the excavated remains of wine-making facilities which can be dated close to his time. Clearly what Palladius had in mind was a substantial wine-making facility, one capable of producing wine on a commercial scale. Can we identify any archaeological evidence for this kind of facility operating in Italy in Late Antiquity?

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[28] Cf. Vitr. *De arch*. 6.9: Vitruvius advises that the *torcularium* should face north but has it located next to the kitchen and bathroom of the villa. Palladius' recommendation to keep the wine press far away from the baths may simply be a reflection of the increased size and sophistication (and therefore heat generating potential) of villa baths in the Late Roman period.

[29] Plommer (1973) 10.

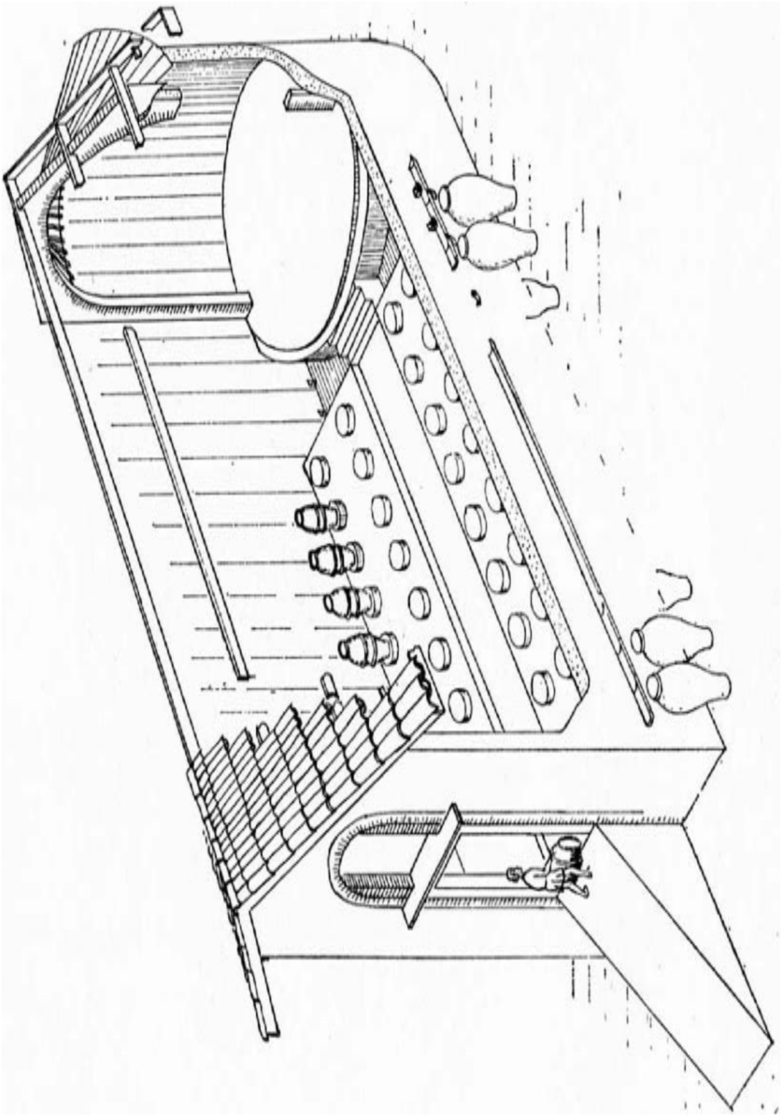

Fig. 5 Hypothetical reconstruction of Palladius' winery, from Plommer (1973).

Sadly, there is, to the best of my knowledge, no excavated and well-preserved winery in Italy whose foundation can be securely dated to Late Antiquity. The best we can hope for, archaeologically, is to find traces of wine-making facilities which, even if we cannot be certain of their date of construction, provide some evidence that they were still in operation during this period.

Some of the best evidence comes from the series of Roman villas excavated on the island of Brijuni off the coast of Istria.[30] Their foundation goes back at least to the Early Imperial period, but recent research suggests that many of the sites, and especially their 'industrial' facilities, were still functioning in Late Antiquity.[31] This would accord well with the evidence of Cassiodorus who describes 6th c. Istria as 'the Campania of Ravenna' (*Ravennae Campania*), a place noted for its excellent vineyards and 'gleaming villas' (*praetoria lucentia*).[32]

Three of the Brijuni villas provide important evidence for wine-making on a commercial scale. One is the villa at Verige Bay, which contained a large winery that has much in common with the kind of facility described by Palladius (fig. 6).[33] Here an elevated brick-paved platform (2), reached by a series of wooden steps (3), served both as the treading floor and the pressing bed for the grapes. No traces of the actual press (or presses) survive.[34] From this platform, the juice flowed down a cut stone channel into a large mortar-lined tank (12), from which it was then distributed into rows of fermentation jars sunk into the floor of the adjacent wine cellar (1). The layout of the winery at Verige Bay villa is closely paralleled in two other nearby villas, those at Kolci and at Castrum. At Kolci, the press-room housed 4 presses, again mounted on a raised brick-paved platform.[35] The villa at Castrum contained two press-rooms (one a later addition) perhaps needed to process both

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[30] Bezeczky (1998); Schrunk and Begovic (2000).

[31] Schrunk and Begovic (2000) 274–75. Bezeczky (1998) 55–68 notes the presence of Late Roman amphorae at all three villa sites.

[32] Cassiod. *Var.* 12.22.1–3, 12.26.3; Schrunk and Begovic (2000) 253.

[33] Gnirs (1906); Bezeczky (1998) 50–57; Schrunk and Begovic (2000) 256; Brun (2004) 53. There has been much debate whether the presses here were used for processing wine or olive oil; Gnirs thought that they were for wine, Bezeczky argues for oil. Brun favours wine but acknowledges that this is not certain.

[34] Begovic's restored plan of the winery puts a single lever press at the centre of the room, but given the multiple presses evident in the other Brijuni villas, this seems unlikely. There were probably at least two presses in the room.

[35] Gnirs (1908); Bezeczky (1998); Schrunk and Begovic (2000) 265–68; Brun (2004) 54.

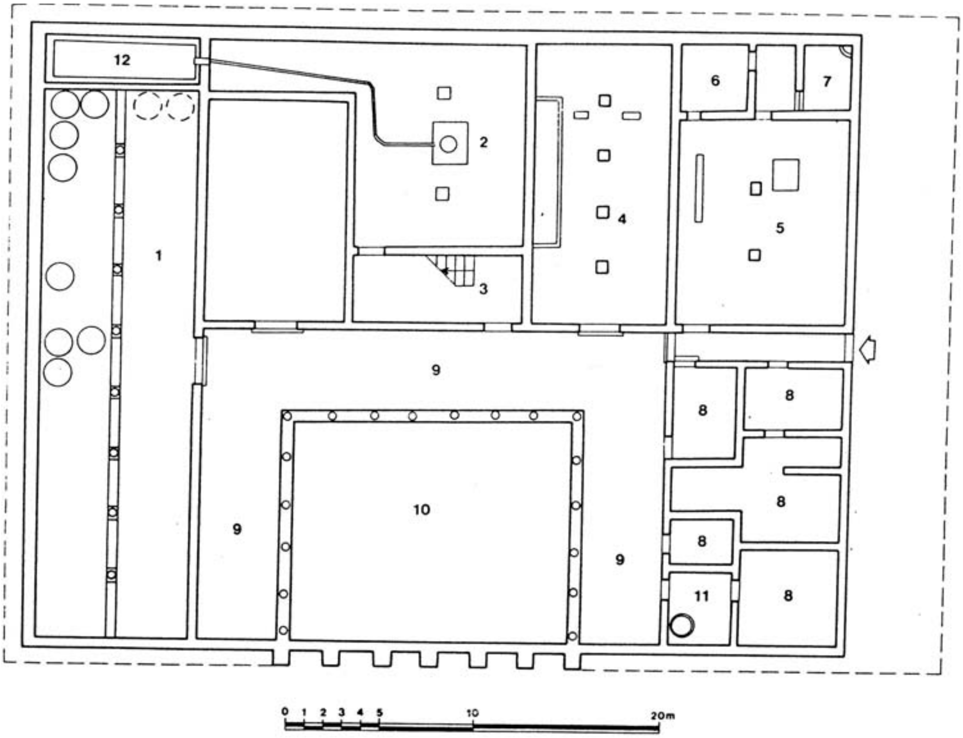

Fig. 6 Winery in the villa at Verige Bay, Brijuni, from Gnirs (1915).

wine and oil, or else to deal with a growing commercial output.[36] At all three sites lever presses were employed. The absence of any winch fittings (as seen for example in the Pompeian presses) and the elevation of the press platforms suggest that they were operated by a screw and weight-stone mechanism of the type described by Pliny.

Another commercial winery, similar in many respects to the Brijuni wineries, can be seen in the Roman villa at Russi, in Emilia Romagna.[37] Again the main components of the winery were a raised brick-paved platform, an adjacent collection tank, and a large wine cellar. The wine cellar, like that described by Palladius, had several interior aisles and what would appear to be supports for barrel racks along the walls. The date of the winery at Russi is uncertain; the *floruit* of the villa appears to be in the 2nd c. A.D., but coin evidence points to occupation at least into the 3rd c., if not later.[38]

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[36] Bezeczky (1998) 62–68; Schrunk and Begovic (2000) 268; Brun (2004) 54–55.

[37] Scagliarini (1968); Mazzeo Saracino (1977); Brun (2004) 48–49.

Very different in layout from these North Italian wineries is a winery found recently at San Giusto in Apulia.[39] The *torcularium* here, which forms part of a Late Roman villa dated by Volpe to the 4th c. A.D, contained two wine presses, both mounted over circular, tile-flagged press-beds (fig. 7). Brun may be right in suggesting that these were direct screw presses;[40] certainly it is difficult to see how lever presses could have been accommodated in the available space. Under-floor pipes led from the press-bed into a large collection tank (lacus) located in the adjoining wine cellar. In the 5th c., the *torcularium* at San Giusto was re-paved and modified with the addition of a new funnelling device and collection tank set into the press-room floor, beside one of the presses.

Wine-Making in Late Antique Italy

The various written accounts of wine-making which we have looked at, rarely indicate the context of the operations they describe. Sometimes we can infer the general locality of the vineyards and wineries which are mentioned, as the authors of the passages can be linked to specific towns, many of them in northern Italy (Aquileia, Verona, Ravenna). But whether the stories of wine-making told by the elites of these North Italian towns relate to large commercial operations on great estates or to small-scale wine-making at urban vineyards is unclear. We might suppose that the former context is more likely, but the evidence from Insula II.5 at Pompeii reminds us that wine-making operations could easily take place at facilities attached to small urban vineyards.[41] Outside Pompeii, however, both material and textual evidence for urban viticulture is rare; the evidence from rural contexts is generally more abundant.

The agricultural productivity of Italian estates in late 4th c. Italy is well-documented.[42] The story told by Ammianus of a riot in Rome in A.D. 375 caused by the elder Symmachus' refusal to sell the wine

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[38] Mazzeo Saracino (1977) 16, where the latest coin listed is of Constantius Chlorus.

[39] Volpe (1998a) 53–65; Brun (2004) 31; Sfameni (2004) 355.

[40] Brun (2004) 31.

[41] Jashemski (1980) 226–28; Rossiter and Haldenby (1989).

[42] Tchernia (1986); Lewit (1991).

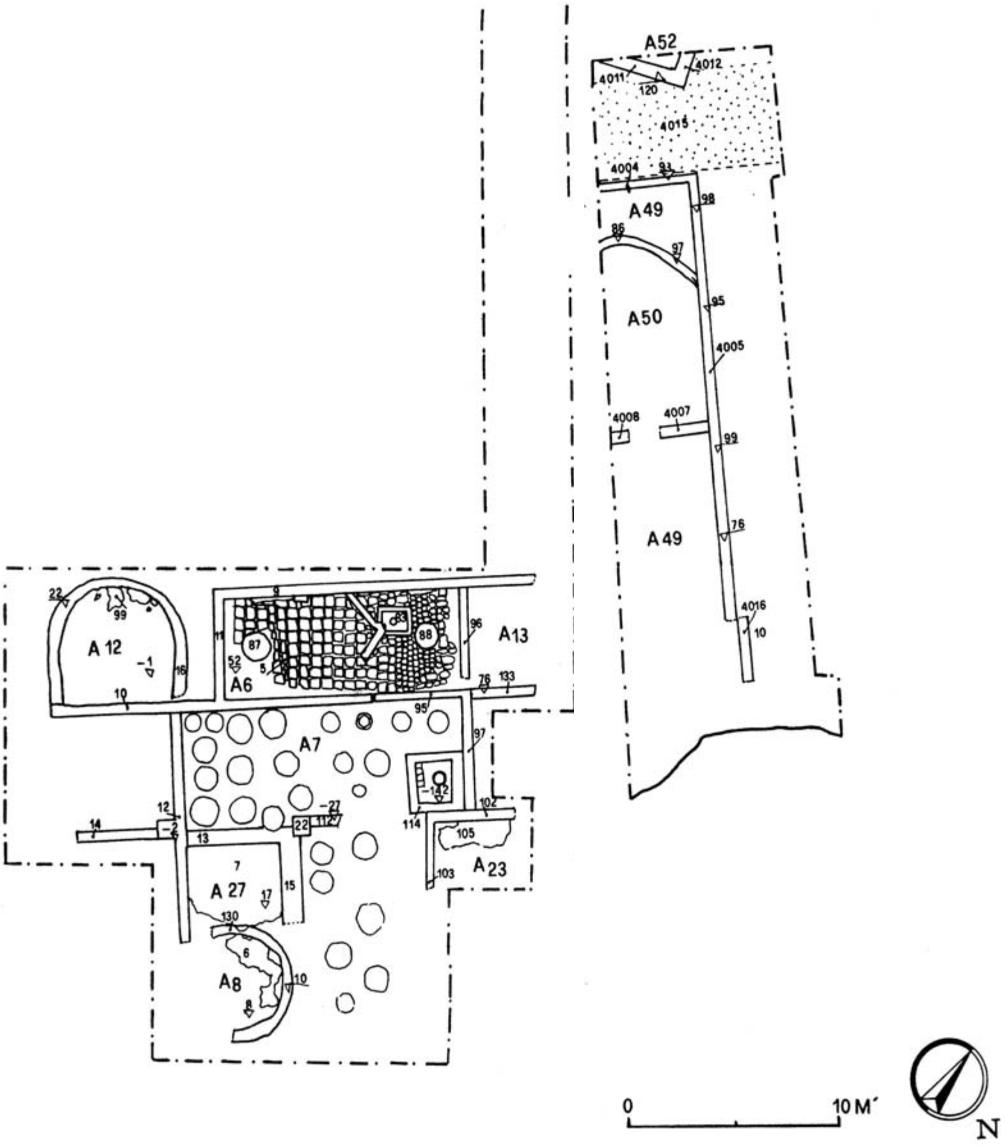

Fig. 7 Winery in the villa at San Giusto, Lucera (Apulia), from Volpe (1998a).

from his estates at an affordable price, offers a revealing picture of contemporary farming conditions.[43] The Symmachi owned numerous estates around Rome, as well as in Campania and elsewhere in Italy, and in all probability many of these land holdings produced wine on a commercial scale.[44] We have already noted textual evidence which alludes to wine-making on some of them. There were many other wealthy landowners whose holdings around Rome were surely no less productive. Aristocratic sources of the late 4th and early 5th centuries are full of reminders of the wealth and produce (including wine) which flowed from these suburban estates.[45]

What evidence is there that these same aristocratic domains continued to produce wine on a commercial scale in the 5th and 6th centuries? There has been much discussion in recent years about the 'fate' of Roman villas (and their estates) in Italy in the post-Theodosian period.[46] The evidence, both textual and archaeological, is fragmentary and the picture which is emerging is still far from clear. There is a considerable amount of archaeological evidence to show that many villa sites experienced some degree of 'change' or transformation during Late Antiquity.[47] Some were abandoned, others re-configured in such a way that once elegant residential quarters were converted to industrial or agricultural use. At the same time, changes of ownership were widespread, in some cases involving the transfer of land from private hands to the Church, in other cases from Roman to Gothic owners. But how these different scenarios of change affected the agricultural productivity of these estates (including in many areas wine-making), is less easy to determine. As Lewit points out, change in occupation does not necessarily imply change in production.[48]

Along with the evidence for change at villa sites in the 5th and 6th centuries, there are also many textual and archaeological indications of continuity, and even revitalisation, of villas. At San Giovanni di Ruoti in Lucania, a new, architecturally innovative villa was built in the early

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[43] Amm. Marc. 17.3; Lancon (2000) 118; Matthews (1989).

[44] Vera (1986).

[45] Macrob. *Sat.* 7.16.15 (wild boar from Tibur); Pasquinucci and Menchelli (1999) 135–36 (wine from Tuscany).

[46] Recent discussions include: Ripoll and Arce (2000); Lewit (2003); Sfameni (2004); Christie (2004).

[47] For the extensive bibliography on this topic, see Chavarria and Lewit (2003).

[48] Lewit (2003).

5th c.[49] A comparable 5th c. villa has been excavated at Quote San Francesco in Bruttium.[50] There are indications in the written sources of continuing productivity at villas in the vicinity of Rome. Palladius owned estates near Rome, the cultivation of which perhaps served as a *mis-en-scene* for his *Opus Agriculturae*, probably written around A.D. 470.[51] From the text of the *Liber Pontificalis*, it is clear that many of the properties transferred to the ownership of the Church in the mid-5th c. brought with them considerable agricultural revenues.[52] One estate in the territory of Caieta provided an annual income of 312 *solidi*;[53] another at Praeneste yielded 92 *solidi* a year. It is likely that the revenues of such estates were derived, at least in part, from the sale of wine.[54]

The writings of Cassiodorus, although heavily infused with nostalgia for the classical past, hint strongly at the continuing capacity of Italian estates to produce wine in both quantity and quality in the early 6th c. A.D. We have already noted Cassiodorus' comments on the vineyards of Istria. Elsewhere, he is keen to praise the wines of his home province of Bruttium.[55] He is especially proud of the wine produced on his own estates near Sqillace (Scylaceum).[56] Indeed, his description of a wine press, quoted above, is very probably based on equipment which he himself owned.[57] The *Expositio Psalmorum* in which it occurs, was written in the A.D. 540's, at a time when the author was living in retirement at his ancestral villa (now converted to a monastery) at Vivarium (fig. 8). Cassiodorus also alludes to the continuing functionality of aristocratic estates in central Italy. In a letter dated A.D. 507–512, the ex-consul Symmachus, a descendant of the great 4th c. orator, is congratulated

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[49] Small and Buck (1994); Sfameni (2004) 350.

[50] Avetta, Marcelli, Sasso d'Elia (1991), Sfameni (2004) 351.

[51] Vera (1999).

[52] E.g. *Lib. Pont.* 42, the estates of the *illustris* Vestina bequeathed to the Church under Pope Innocentius I (A.D. 401–417); *Lib. Pont.* 46, the estates of the Urban Prefect (?) Bassus confiscated by the Church under Pope Xystus (A.D. 432–40). On the value of church estates in late antique Italy, see Pasquinucci and Menchelli (1999); Pietri (1978).

[53] *Lib. Pont.* 46.

[54] Details of agricultural output are not given in the *Liber Pontificalis*; the only reference to wine concerns the use of wine *cellae* for private drinking (*Lib. Pont.* 43: Zosimus, A.D. 417–18).

[55] Cassiod. *Var.* 8.31.5, 12.12.1, 12.15.5. Sirago (1987), Barnish (1987).

[56] Cassiod. *Var.* 12.12.5, where he mentions wine from his own *cellae*. On Cassiodorus' estate at Squillace: Courcelle (1938), O'Donnell (1979).

[57] For farming activities at Cassiodorus' estate, see O'Donnell (1979) 193–94; Cassiodorus says that a copy of Columella's *De Re Rustica* was among the codices kept in the library (*Inst.* 1.25, 28, 31).

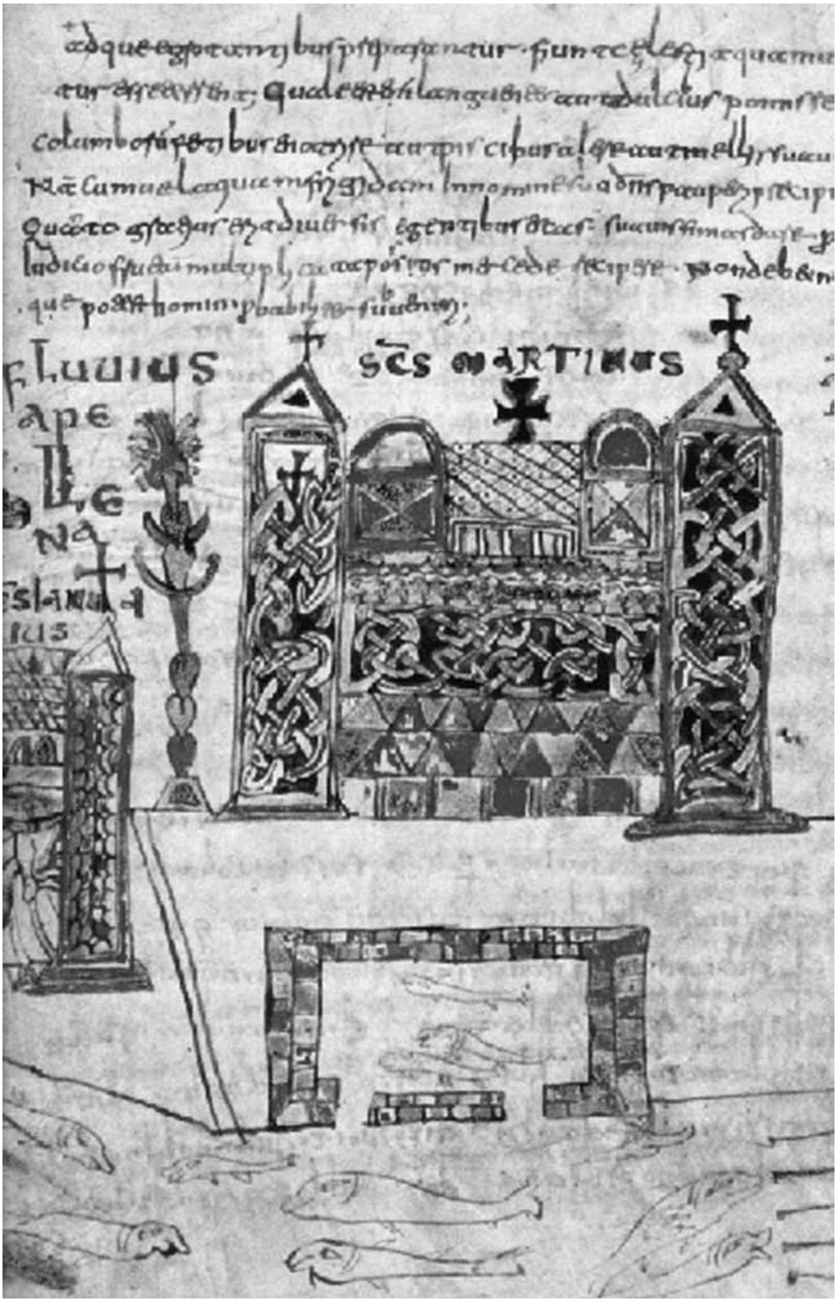

Fig. 8 Manuscript illustration of Cassiodorus' villa near Scylaceum (Calabria) (Bamberg Cassiodorus, 8th c. A.D., with thanks Staatsbibliothek Bamberg Msc. Patr. 61, fol. 29v).

for his private building projects—presumably the restoration of ancestral villas—in the *suburbium* of Rome.[58]

This picture of sustained agricultural activity, and even investment, is supported by an increasing volume of archaeological evidence, both for the late occupation of villa sites in Italy and for the movement of Italian wine amphorae to major urban centres during the 5th and 6th centuries. Villas which have produced evidence for 6th c. occupation include Piazza Armerina,[59] Massaciuccoli,[60] Cazzanello,[61] and Agnuli.[62] And, as was noted earlier, new pottery evidence from the major wine-producing villa at Val Catena on the island of Brijuni, also points to some form of continued late use of the facilities.[63] In addition, new studies of wine amphorae, in particular of the Italian Keay 52, have shown a healthy trade in wine from South Italy destined for Naples and Rome and, in smaller quantities, to destinations outside Italy during the 5th and 6th centuries.[64] This trade included shipment of Italian wine to Constantinople, where examples of probable Italian wine amphorae have been found in 6th c. contexts at Saraçhane.[65] According to Corippus, the wines served at the coronation banquet of the emperor Justin II at Constantinople in A.D. 565, included wine from Italy, identified, perhaps rhetorically, as 'Falernian'.[66]

Conclusions

The 'history' of wine-making in late antique Italy cannot be written in detail. However, enough textual and archaeological evidence survives to give us at least a glimpse of the continuation of wine production in different parts of Italy during the late antique period. By and large, the evidence suggests strong ties to traditional methods of wine-making. There is no hint of innovation in processing techniques and no indication of mechanical advances since the time of Pliny. Although not mentioned by all authors, there can be little doubt that the traditional horizontal lever press remained in widespread use. This contrasts with the situation in the eastern Mediterranean where the use of vertical or direct-screw presses appears to have become increasingly common in Late Antiquity.[67] Where clues exist to the type of mechanism employed to raise or lower the press beam, they generally point to a lever-and-screw mechanism using stone weights. This is implied in the descriptions of presses given by Zeno and Cassiodorus and by the relief image of a Late Roman press from Aquileia. Winch-operated lever presses of the Catonian type seem to have remained in operation too. It was probably cheaper to repair old winch-operated lever presses than to install new screw presses. The use of horizontal lever presses in Italy endured well beyond the Classical Age which invented them: as late as the 10th c., Luitprand of Cremona mentions a wine-press built in traditional manner, with the usual vertical wooden posts (*arbores*) which supported the beam at the front of the press.[68]

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[58] Cassiod. *Var.* 4.51.1–2.

[59] Carandini, Ricci and de Vos (1982) 376–77; Sfameni (2004) 349–50.

[60] Campoltrini (1995).

[61] Aoyagi (2002–3).

[62] Volpe (1998b).

[63] Schrunk and Begovic (2000) 274.

[64] Arthur (1989); Reynolds (1995); Pacetti (1998); Durliat (1998).

[65] For probable Italian wine amphorae at Saraçhane, see Hayes (1992) 67, types 13 and 14; Morrison and Sodini (2002) 210.

[66] Corippus *Laud. Just.* 3.97.

Only rarely is it possible to link the different types of presses, alluded to in the textual sources or illustrated in late antique art, to specific modes of wine production. In the Late Roman period, much of the evidence points to commercial production based on the great villas of aristocratic families. The transformation and abandonment of some villa sites in the 5th and 6th centuries, brought about by fundamental social and political change, must have caused some disruption to these centuries-old patterns of agricultural production and commerce. Yet, as Lancon notes, even tumultuous events like the Gothic and Vandal sieges of Rome in the 5th c. and the Byzantine wars of the 6th c., may not have seriously affected the traditional exploitation of the Italian countryside.[69] The pattern of wine production hinted at in the pages of Symmachus is still visible in the writings of Cassiodorus, whose family's vineyards in Bruttium, now part of a newly-formed monastic community, continued to produce wine on a commercial scale in the early 6th c. By the end of the 6th c., the organised trade in wine may have diminished, but Italian vineyards continued to produce wine for local markets using technologies little changed from the time of Pliny.

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[67] For this distinction between eastern and western press technology: Morrison and Sodini (2002) 198. On presses in the eastern Mediterranean in Late Antiquity, see Lewit in this volume.

[68] Liutprand of Cremona, *Hist.* 6 (= *PL* 136.895C): *quo torcularium arbores subvehuntur*.

[69] Lancon (2000) 39ff.

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ABSENT-MINDED LANDLORDS AND INNOVATING PEASANTS? THE PRESS IN AFRICA AND THE EASTERN MEDITERRANEAN

Tamara Lewit

Abstract

The screw mechanism for wine and oil presses was widely applied in the eastern Mediterranean only in Late Antiquity, about half a millennium after its invention. This occurred in relation to a great intensification of commercial production in this region, including the bringing into cultivation of marginal land and the occupation of new areas. However, why was a screw mechanism not used in other important export regions, such as North Africa? Case studies of settlement patterns in a number of regions suggest that the absentee landlords of large estates seem to have been less inclined to adopt changed technology, whereas resident owners—whether of large or small estates—living close to their land, and directly involved in the processes of production, may have been more likely to do so. Among the many factors at play—technical, geographic, cultural, chronological, environmental, and commercial—the relationship of the landowner to his land may have played an important role in the diffusion of technology.

The Explosion of Settlement

One of the clearest developments in the recent scholarship of Late Antiquity has been the archaeological discovery and increasing recognition of rural settlement expansion, intensification of land-use and commercially-based prosperity in the 4th to 6th c. A.D. eastern Mediterranean. In many regions, marginal land was brought into cultivation again or for the first time. Discoveries of buzzing rural settlement are consistent and widespread. The example of the North Syrian villages is the best-known. In this marginal massif region, the 5th to 6th centuries were the period of most intensive agricultural exploitation and of peak prosperity, with village populations and building activity reaching

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(Late Antique Archaeology 4 – 2006) (Leiden 2007), pp. 119–139

their highest point.[1] East of Petra also, these centuries saw an intensification of settlement and land-use.[2] In Jordan, a number of surveys have revealed an "explosive growth" of rural settlement, including in marginal regions, in this period.[3] Recent publications have documented an increase in agricultural exploitation, wealthy rural building, and the flourishing of amphora and wine workshops in the Alexandrian hinterland region of Egypt in the 5th to 6th centuries.[4]

In Palestine, there is extensive survey evidence for prosperous farmsteads and villages, with new settlement and often intensification of land-use—expanding into marginal areas in many regions—in the 4th to 7th centuries.[5] In Samaria, new "villages and farms were founded by the dozens" and cultivation intensified and expanded to the hills.[6] This picture is supported by excavations, which have revealed significant new building from the 4th c. onwards: for example, the village of Korazim was built mostly in the 4th c.,[7] and that of Sumaqa, a mountain settlement with intensive agricultural cultivation, reached its maximum size in the same period.[8] One of the most outstanding examples is the flourishing of agricultural settlement in the Negev desert, where highly intensive land-use for oil and wine production was extended, and elaborate dams and agricultural installations were built.[9] A later floruit has emerged for the Dor hinterland, with a great increase in settlement and commercial viticulture in the second half of the 5th c.,[10] and the Modi'in region, where extensive viticulture flourished in the 6th to 9th centuries.[11]

In Asia Minor, villages in Cilicia show a short peak in occupation in the 5th to early 6th c.[12] A similar expansion in the number of villages and farms may have occurred in the central region of Lycia in the same period, although dating is uncertain.[13] In Pisidia, recent survey has shown a pattern of increased settlement and re-occupation of earlier sites in the 4th to 5th centuries.[14] A dramatic 5th to 7th c. increase in the number of rural sites occupied, their size, and the intensity of land-use has been revealed by survey on the Konya Plain.[15]

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[1] Tchalenko (1953); Callot (1984); Tate (1992).
[2] Fiema (2002).
[3] Summarised in Walmsley (1996) 150–52.
[4] Haas (2001); Empereur cited in Amouretti (1993) 581–82.
[5] Hirschfeld (1997); Bar (2002); Safrai (1994); Kingsley (2001) 44.
[6] Ayalon (1996).
[7] Hirschfeld (1997) 33–71.
[8] Dar (1999).
[9] Rosen (2000); Patrich (1995) 485.
[10] Gibson, Kingsley and Clarke (1999).
[11] Gibson (2003) 8–10.
[12] Rossiter and Freed (1991).
[13] Foss (1994).

A diverse range of patterns has been revealed by surveys in different regions of Greece. A number of these, although by no means all, show some intensification of settlement from the 4th to 6th centuries. In the Lasithi region of Crete, the number of 4th to 6th c. rural sites seems to have exceeded that of any earlier period.[16] The Methana survey shows greater exploitation of land and an increased number of rural settlements, especially small to medium sites with oil and wine pressing equipment.[17] Excavations and survey projects in Cyprus demonstrate a new increase in the density of rural settlement in various regions of the island during the 5th to 6th centuries.[18] The excavation of the rural centre of Kopetra has revealed a prosperous agricultural village, which was first occupied in the 5th c. and grew substantially in the 6th c., when three churches were built.[19]

Although the evidence of field surveys and figures for occupation levels in different periods must always be treated with due caution, and with attention to methodological issues, the evidence for a boom in settlement and land-use is so consistent and widespread, and moreover, supported by that of excavated sites, that it is now generally accepted.[20]

It is clear that this intensification of rural settlement represents, in many cases, growth in levels of agricultural production, well above subsistence level and often—even at small villages and farms—on an impressive commercial scale. This is also evidenced by finds of late antique Palestinian wine amphorae as far west as Spain, France and Italy,[21] and of those produced in kilns of the Mareotis region—in association with its wine production[22]—in large quantities in western Mediterranean shipwrecks and sites.[23] It is consistently noted by scholars that the existence, density and size of presses for wine and oil production in regions such as North Syria, Palestine and the Methana peninsula indicate a high level of commercial production, well in excess of local needs.[24] A typical example is that of Sumaqa, where the small settlement of about 20 stone-built houses appears, from the capacity of the presses, to have produced possibly about 200,000 litres per annum of wine.[25]

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[14] Vanhaverbeke *et al.* (2004).

[15] Baird (2004).

[16] Bintliff (1997).

[17] Bowden and Gill (1997b).

[18] Rautman (2000); Papacostas (2001); Papageorghiou (1993).

[19] Rautman and McClennan (1992); Rautman (2003).

[20] Whittow (2003); Discussion in Lewit (2004) xi–xii.

[21] Kingsley (2001).

[22] Empereur (1993) 46.

[23] Haas (2001).

Technological Diffusion

An area of technology central to this production is the mechanism of the presses used for the second stage of both oil and wine production, when carried out on a commercial scale. This has received increasing attention in recent years and can be partially illuminated in the light of excavations and surveys. As has been noted by a number of scholars, the use of the screw for the pressing process was the first major innovation to press technology since the introduction of the lever in the Bronze Age.[26] This also entailed subsidiary innovations, for example, to the form of weight-stones.[27]

The application of the screw to press technology was famously described by Pliny and Hero in the 1st c. A.D. as an innovation then already about a century old.[28] However, very few actual examples of such presses dated to this early period have been found in any region of the Roman Empire. There seems rather to have been a large degree of conservatism and continuity in the use of age-old techniques.[29] It is only in Late Antiquity, in the context of the prosperous and expanding East described above, that we have clear evidence of the widespread diffusion of the use of a screw mechanism for wine and oil presses.[30] In Palestine, both lever and screw and direct screw presses have been found, catalogued and in many cases dated. Virtually all dated examples are 4th c. A.D. or later.[31] In Cyprus, lever and screw types have been found and catalogued: none pre-date the 4th c.[32] No remains have been found of direct screw presses, although it has been suggested that, due to the abundance of suitable wood in this region, they may have been made entirely of timber, and thus may not have survived archaeologically. Such presses with timber press-beds were used in Cyprus in later periods.[33] In Cilicia, the excavation of an oil installation at Domuztepe has revealed the use of a lever and screw press at a village mainly occupied from the 5th to the early 6th c.[34] In the North Syrian villages, Tate has documented 245 presses,[35] studied in detail by Callot,[36] of which the great majority were lever and screw. No direct screw presses have been identified.[37] The 4th to 7th centuries were the most intensive period of settlement in this region, when much building was undertaken, and it has been concluded that the presses date from this period.[38] In Egypt, 16 wineries in the Mareotis region have been recently catalogued and dated. Of these, 9 contain presses, all using a direct screw mechanism, and all dated to the 5th to 7th centuries.[39]

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[24] For e.g., Decker (2001); Foxhall (1997) 263; Rosen (2000); Patrich (1995) 485.

[25] Dar (1999) 138.

[26] Frankel (1999) 62, 107.

[27] Hadjisavvas (1992) 61. Other areas of innovation included changes to methods of mounting the press beam: Mattingly (1996) 579–80.

[28] White (1975) 229–32; Frankel (1999) 107.

[29] Brun (1993b); Frankel (1999).

[30] While there has been much debate about which presses may have been for oil, which for wine, and which for both, this will not concern us here: see, e.g., Tate (1992) 243–45; Frankel (1999) 155; Decker (2001) 79–80; Brun (1993a). It is also beyond the scope of this paper to discuss the great variety in the types of screw presses and their

Why Diffusion?

On the basis of current knowledge, we can conclude that while the new screw press technology was not an invention of the late antique period, it was apparently only in the context of the villages, farms and villas of the late antique East—about half a millennium after its invention—that

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components: see, e.g., Callot (1984); Hadjisavvas (1992); Frankel (1997) and (1999); Brun (2004).

[31] Frankel (1999) 117; Brun (2004) 128–33; the only known exception is that of Korazim, which has been dated to the 2nd c. A.D.: Frankel (1999) 132; Kloner cited in Brun (1993b) 545. My grateful thanks to R. Frankel for his advice and discussion of these points.

[32] Hadjisavvas (1992) 84, (1996), and cited in Brun (1993b) 546.

[33] Hadjisavvas (1992) 77.

[34] Rossiter and Freed (1991).

[35] Tate (1992) 243.

[36] Callot (1984).

[37] Callot (1984) 32–53.

[38] Tate (1992) 318; Brun (2004) 119.

[39] The remaining seven wineries (three Early Roman, four 6th–7th c. A.D.) do not contain any presses: Rodziewicz (1998).

it was widely applied. Why did the diffusion of technological change occur there and then?

We have noted above that there was obviously a great intensification of production in the late antique East, including the bringing into cultivation of marginal land and the occupation of new areas. People engaged in this production were prompted to adopt different methods in spite of the widely-noted longevity of traditional agricultural technology.[40] It seems apparent that they did so in relation to a new level of commercially-oriented production. The very existence of presses is evidence of commercial-scale production, as subsistence production does not actually require grapes or olives to be pressed after crushing. It has been argued that where the output of a traditional press fulfils the needs of a local group, there will be no motivation for technological change; only in the case of a radically changed situation—such as a new commercial installation—and only in the case of production for sale, rather than for self-sufficiency, would the productive potential of a screw press be seen as preferable.[41] This is precisely the situation which we can identify in the multiplying villages and farms of late antique Palestine, Cyprus, Asia Minor, Egypt and North Syria.

In the new villages and farms which were being established, often in new and more marginal regions, we see a unique situation: not only were these settlements apparently market-oriented, but they were also often investing in and building new installations, rather than adapting or re-using existing equipment. Considerations such as the prior existence of large, long-lasting and expensive installations would have had a much-weakened effect in these circumstances. Moreover, reducing the size and expense of setting up a new installation by the application of a screw (see below), would have been more important. Technological diffusion may also have been favoured by the engagement of such farmers in trade with the world beyond their local region.

However, if we are to invoke the commercial scale of production and the demands of setting up new installations as an explanation for the spread of screw press technology, we are faced with a compelling question: why were such presses never used in the prime oil-producing regions of Tunisia and the Tripolitanian Gebel? In these regions, we see what was obviously an intensive commercial production, which was newly-established in the imperial period and peaked in the 3rd c. Here, huge numbers of presses have been found, including both large installations, with multiple presses, and smaller establishments—often in more marginal land—with only one or two. These presses are exclusively of the lever and windlass, not screw, type, although they are clearly directed to commercial production on a very large scale.[42]

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[40] For a discussion of theoretical approaches to technological innovation in pre-industrial periods, see Greene: (1994) and (2004). Greene emphasises the importance of the socio-economic context of technology. Considerations of such socio-economic factors are prominent in current analyses of Late Roman press technology.

[41] Amouretti *et al.* (1984) 418–20.

A similar puzzle has been revealed in the Methana region of Greece. Here, in the context of new 4th to 6th c. settlement, there is a density of presses unparalleled elsewhere in Greece and among the highest in the Mediterranean region. The density is comparable to that found in North Africa, although the individual presses are far smaller in scale. An estimated output of perhaps 20,000 kg of oil per harvest may have been intended for the nearby cities of Corinth, Athens or Constantinople, or for more far-flung trade.[43] In this region, as in Tunisia and Tripolitania, the presses used were of the lever and windlass or counterweight type and did not employ a screw mechanism.[44]

We are thus confronted with a glaring contrast between the extensive commercial exploitations of Methana, Tunisia and Tripolitania, where the screw was not applied, and those of North Syria, Cyprus, Palestine and Egypt, where it was. How can this be explained? Although the peak of Tunisian/Tripolitanian settlement and oil production was slightly earlier than that of the eastern Mediterranean,[45] it still easily post-dates the invention of the screw and its description in texts. The flowering of production at Methana is of a very similar date to that recorded elsewhere in the eastern Mediterranean.

First, we need to consider a range of factors which would influence the choice of press type when constructing a new installation. These include:[46]

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[42] Mattingly and Bruce Hitchener (1993); Mattingly (1988) and (1995); Frankel (1999) 94.

[43] Foxhall (1997) 263.

[44] Foxhall (1997); Frankel (1999) 105.

[45] The boom appears to have occurred in the 2nd to 4th centuries A.D.: Mattingly (1988); Bruce Hitchner (1990).

[46] See also summary in Amouretti (1993). My grateful thanks to Robert Lewit for his technical advice and discussion of these points.

1. Geographic Proximity to Sources of Expertise

Geographic proximity to sources of expertise may have influenced the diffusion of technology. Regions such as Syria, Palestine and Egypt were simply closer to each other than they were to Tripolitania, for example. The construction of a screw press requires local access to the technical expertise to create an effective screw thread.[47] However, geographic proximity to sources of expertise does not always seem to have been decisive in effecting diffusion: the region of Methana, for example, does not seem to have drawn on the expertise which produced the screw presses used in nearby regions of Greece and the Aegean.[48] Northern Africa is not a great distance from Cyprus and Egypt, where screw technology was applied. An ethnographic study of 18th c. Corsica has shown that on this one small island, a diversity of press technologies were known and used: the direct screw press was used in some districts, but there remained a great predominance of the simplest lever presses, in spite of the ready access to alternative technology.[49] We may also note that we would expect access to expertise to be generally good in the context of the market-oriented settlements we are discussing, since they had constant and extensive trade contact with other regions.

2. Scale and Speed of Production

Scale and speed of production can be increased by a range of strategies, including enlarging the press and its elements, multiplying the number of presses, or employing more advanced technology such as a screw or a double screw. A crucial factor is whether the requirement is for a single, efficient pressing of a large quantity of olives/grapes, or whether a number of smaller quantities (e.g., from different producers) need to be pressed separately. It is also important to note that a press using a screw is not automatically more productive than one which does not: their relative efficiency and output depend on their relative size and that of various components.[50]

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[47] Note the inscription naming the wood and carpentry workers who constructed a press at Kafr Nabo: Brun (2004) 120. My grateful thanks to David Campbell for his technical advice on this point.

[48] Frankel (1999) 119 for Attica, Lesbos and Pontus; Brun (2004) 74–78 for Peloponnese and Attica; Rossiter and Freed (1991) for Cilicia.

[49] Casanova (1993).

[50] Mattingly (1996).

3. Size of Installation

A direct screw press is smaller, more portable and uses less space and materials than a lever press. This could possibly have been a consideration in setting up new presses in more inaccessible highlands, although we may note that in the North Syrian massif, to which there would have been difficulty in transporting large wooden beams, the type used is the lever and screw, not the direct screw. In the case of the largest presses, this would have entailed the importation of suitable wood. However, the use of a screw, even with a lever, can improve the output of a smaller-scale press without increasing its size. It has been calculated that the smaller presses of this region could have used beams of local wood.[51]

4. Expense of Materials and Manpower for Construction

The construction of large lever presses required huge stones for the orthostats, large straight wooden beams for the lever, and the input of substantial financial capital and organisation of manpower. Many of the Tunisian examples are of massive size, with stone orthostats of up to 2–3 m high, weighing 2–3 tonnes, and with a beam 9 m or more in length.[52] At Sumaqa, the lever press weightstones alone were more than 1 m high and weighed more than 1,000 kg each.[53] As discussed above, a major consideration would be whether there were already existing installations, which would have been very durable and would have represented considerable capital.[54] It should be noted that large lever and screw presses—as opposed to direct screw presses—could still require large components: e.g., the exceptionally large lever and screw press at Hirbet Najar in Samaria used 2.4 m high orthostats and a beam probably 6 m or more in length.[55] One screw press at Sarfud in North Syria used an 8 m beam, with a screw weight of 800 kg.[56]

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[51] Callot (1984) 86–87, 125.

[52] Mattingly and Bruce Hitchner (1993).

[53] Dar (1996) 160.

[54] Frankel (1999) 176.

[55] Dar (1986) 176.

[56] Brun (2004) 117.

5. Availability and Organisation of Manpower for Operation

Lever presses may be operated by a single person,[57] whereas a screw press requires greater manpower to turn the screw.[58] Callot has estimated that 2 to 4 workers would be needed to operate the North Syrian mechanisms, and a total of 7 to 10 workers to operate a whole oilery.[59] Since a press has only a short season of use, the availability of labour during this short time would be a major consideration.

Settlement and Technological Diffusion: Case Studies of Production for Export

In seeking explanations for the contrast between the presses in regions which did or did not apply the screw, one factor which has been little explored is the nature of the socio-economic groups constructing and using the presses. Archaeology can provide us with some clues in the form of the settlement patterns revealed by survey and excavations. Can this particular body of data shed any light on divergences between regions where the screw was not applied, and those in which it was? Can we find any distinctions in settlement types between these regions, which may suggest differences in the nature of the socio-economic groups constructing and using presses?

In exploring these questions, I will take the examples of several regions: the Mareotis region of Egypt, North Syria, and Samaria and Galilee in Palestine, where screw presses were used; and the Segermes and Kasserine regions of Tunisia, the Tripolitanian Gebel, and the Methana region of Greece, where they were not. These examples have been selected on the basis of two criteria: firstly, that in these places there was, in the 3rd or later centuries A.D., an intensive wine and/or oil production at a commercial level for export beyond the local region, and thus a real need for the efficient pressing of olives or grapes; and, secondly, that both settlement and productive structures have been well-investigated for these regions. I will compare these regions in terms of two settlement issues: the pattern of settlement; and the nature of occupation at those settlements.

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[57] Mattingly (1993) 495.

[58] Amouretti *et al.* (1984) 418–20.

[59] Callot (1984) 99.

The Pattern of Settlement

In North Syria and the Samaria and Galilee regions of Palestine, the typical pattern of settlement was the village. A typical example in Samaria is the *ca.* 3 ha nucleated settlement of Hirbet el-Buraq: about 60 houses of dressed stone, each about 10 × 20 m, clustered along a main street and a series of alleys. There was a small church with polychrome mosaic of the 5th or 6th c., a large agricultural and workshop area with cisterns, reservoirs and threshing floors, three wine installations—one of which was very large and incorporated a screw press—and two or three oil presses. Further wine and oil presses have been found in the surrounding agricultural area, in spite of the marginal nature of the local soil.[60] The famous North Syrian villages were mostly somewhat smaller, usually about 2 ha, with 20–30 stone-built houses, and without a formal street plan. As in Palestine, public buildings were rare, except for churches. Each village usually had a number of presses.[61] It should be noted that these northern villages are well-known to us, not because they are necessarily representative of broader patterns of settlement in the East, but because they were preserved due to the later desertion of these regions. The flourishing of these villages in such a marginal area represents a notable intensification of settlement and production, but must have been only part of the wider picture.

Within the villages in these regions, there seems to have been little socio-economic hierarchy, with only modest distinctions in size or rank between houses.[62] Where larger and more privileged dwellings do appear—for example, those at Korazim in Palestine and Behyo in North Syria, located nearer to the synagogue and the church respectively[63]—these evidently belonged to more prosperous inhabitants, but are not so greatly distinguished from other houses as to suggest that the occupants were of a radically different rank.

It has been the tendency of scholars to believe that in the late antique period, such villages were occupied primarily by peasant owners of local farms.[64] The Nessana papyri provide evidence of independent peasant cultivation in Palestine, although from a more southern region.[65] Textual evidence suggests that there were also some smaller villages which were part of large estates,[66] and an inscription indicates the existence of one imperial estate in the North Syrian massif, associated with an exceptionally large residence.[67] However, the combination of both textual and archaeological evidence leads to the conclusion that villages of independent peasant landowners were an important part of the rural landscape of this region.[68] While it is impossible to use archaeology to decide the legal relationship to the land of those who occupied a building, the village houses were certainly well-built and look prosperous and substantial, although not luxurious. The appearance of these habitations suggests that their occupants were the actual owners of the land. If they were tenants,[69] the style of their habitations suggests that this was more a legal than a real distinction, and that they enjoyed a degree of status and profit from their land equivalent to that of peasant owners.

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[60] Dar (1986) 51–73; Frankel (1999) catalogue no. 000 1616 08 001.

[61] Tchalenko (1953); Callot (1984); Tate (1992).

[62] Dar (1986); Gatier (1994); Foss (1995); Hirschfeld (1997).

[63] Hirschfeld (1997) 42; Tate (1992) 265–67.

[64] Hirschfeld (1997) 36–30 for Palestine; Tchalenko (1953) 408; Tate (1992) 269 for Syria.

A very different settlement pattern appears in Tunisia and the Tripolitanian Gebel. Here, there were fewer villages, more dispersed sites and a more strongly-marked hierarchy. For example, the Kasserine survey in Tunisia has documented a few large sites with substantial central buildings and press complexes, which seem to be large estate-centres. Site KS 225 is associated with a monumental tomb. Site KS 022, which extends over more than 8 ha, consists of an estate-centre organised around a courtyard of work buildings, remains attesting oil production, what is interpreted as a residential area with a possible peristyle, a small bathhouse with geometric mosaic, and an associated small village. There are many noticeably smaller agricultural settlements—with smaller structures and without central buildings—and small courtyard buildings, which are often close to the larger settlements. These smaller sites have been interpreted as the residences of small tenants, *coloni* or slaves, an interpretation supported by the evidence of the Albertini Tablets.[70] In the Segermes region of Tunisia, there is a similarly pronounced hierarchy, with a few large settlements attributed to major landowners, and much smaller productive sites and villages, with few finds of imported goods, which surveyors attribute to dependent *coloni*.[71] In the Tripolitanian Gebel, 1st–2nd c. A.D. settlement was in the form of large farmsteads (or, occasionally, near the coastal cities, decorative villas) with groups of huge presses. Evidently high status, fortified *gsur* developed in the 3rd to 4th c. Several have been linked to elite estates.[72]

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[65] Mayerson (1962); Morrison and Sodini (2002) 183.

[66] For e.g., Hirschfeld (1997) 36; Liebeschuetz (1972) 67.

[67] Tchalenko (1953) 393.

[68] Liebeschuetz (1972) 65–73, (1988); Banaji (2001) 10–11; Morrisson and Sodini (2002) 183; Trombley (2004).

[69] Discussion in Gatier (1994).

[70] Bruce Hitchner (1988) and (1990).

We may conclude that the settlement pattern of these regions was probably one of large (many possibly imperial) estates.[73] Thus the massive African presses seem to have been set up by the powerful landowners of large estates, who could command and co-ordinate huge resources for construction. The enormous capacity of these presses would be suitable for processing large-scale harvests as quickly as possible.[74] This supports the current view of great estates as highly commercialised and market-oriented.[75] It also confirms legal evidence that on large estates farmed by dependent tenants, the landlords provided large and expensive equipment such as presses as part of the tenancy agreement.[76]

In contrast, we would expect peasant villagers, such as those of Palestine and North Syria, especially when expanding production into new marginal areas and, therefore, building in new locations, to prefer technology which required a smaller quantity of expensive materials and more modest organisation of manpower to construct. We would also expect a tendency to construct installations with a number of smaller-scale presses to be used by separate producers, each harvesting a smaller quantity than would be produced by a large estate. Such village presses might be either co-operative or individually owned,[77] but even if they were co-operative, it might be preferable to process a number of smaller quantities of olives/grapes from different producers separately, rather than to mix them together and press them at once. In this case, a number of smaller presses, more efficient in the use of space and materials, would still be preferable to a single huge press. Most North Syrian villages seem to have had such multiple presses.[78]

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[71] Ørsted *et al.* (1992).

[72] Mattingly (1995) 141–44, 202–09.

[73] Mattingly and Bruce Hitchner (1995).

[74] Mattingly (1988) and (1993) 484.

[75] Sarris (2004a) and (2004b).

[76] Foxhall (1990) 108.

[77] Tate (1992) 249.

[78] Tchalenko (1953); Callot (1984) 117–22; Decker (2001) 73.

Callot attributes the building of multiple, modestly-sized presses at Bamuqqa in North Syria to the replacement at the start of the 5th c. of a single estate by about 20 individual farms.[79]

Can we thus conclude that there was a greater tendency to adopt technological change where there was village settlement and fewer distinctions in rank or size within settlement, and a lesser tendency to change where there was more dispersed settlement and a more strongly-marked socio-economic hierarchy? Can we draw an inference that peasants were more inclined to adopt different technologies than the owners or cultivators of large estates? Here we may note Foxhall's critique of the assumption that peasant cultivation tends to subsistence in contrast to the market-oriented, large estate.[80] Decker contrasts the "abundance of small presses in modest-sized villages" of Syria with the massive African oil installations which appear to be located on large estates, and concludes that the Syrian examples "represent the small Late Roman farmer operating outside the estate".[81] If this pattern is confirmed by further study, it clearly throws doubt on the assumption of the supposed innate 'conservatism' of peasants,[82] an assumption sometimes called upon to explain the patterns of ancient press technology and use.[83] In the 5th and 6th centuries, we see innovating peasants, who built new villages, colonised marginal areas of land, and adopted changed technology. However, in terms of the regions which we have set out to examine, this pattern is not entirely consistent: the village setting we find in North Syria and in Galilee and Samaria is not duplicated in the Mareotis region of Egypt, where we also find diffusion of technology. The Mareotis wineries are rather associated with luxurious villas, often embellished with baths, frescoes, and imported marble.[84] Examples such as the 5th c. double-peristyle villa and winery at Huwarriyah have led scholars to the conclusion that "the economy of Mareotis was in the hands of landowners of good-sized farms and vineyards",[85] a conclusion supported by textual evidence regarding landownership patterns in this region.[86] The wineries found in association with such Mareotis villas have multiple screw-operated presses.[87] Nor was the village the invariable pattern of settlement in Samaria and Galilee: large farmhouses have also been found, such as those of Hirbet Bastin and Deir Sam'an in Samaria[88] and Khirbet el-Quseir in western Galilee.[89] While they are less decorative and more functional than those of the Mareotis region, and lack bathhouses, they are large complexes of around 50 × 50 m, and appear to have been residential estate centres—the local equivalents of the villa. We thus find the adoption of changed technologies not only in peasant villages, but also in richer estate centres which have the appearance of belonging to the owners of substantial estates.

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[79] Callot (1984) 119–20.

[80] Foxhall (1990).

[81] Decker (2001) 82.

[82] First established by sociologists M. Weber (in *Die protestantische Ethik und der 'Geist' des Kapitalismus* (Berlin 1904–1905)) and E. Rogers (in *Modernization Among Peasants: Impact of Communication* (New York 1969)).

[83] For e.g., Avni and Gudovitz (1996).

[84] Empereur (1993).

[85] Haas (2001) 53.

The Nature of Occupation

Perhaps light can be shed on this question by examining a second point of comparison: what is the nature of occupation at the settlement sites in each region? The question of who occupied a habitation, and the relationship of that inhabitant to the surrounding agricultural unit, is a thorny one for archaeologists. As emphasised above, it is impossible to use archaeological evidence to prove the legal relationship to the land of those who occupied a building. However, historical and archaeological study is by its nature a constant attempt to draw tentative conclusions on the basis of inconclusive evidence. Just as we speculatively extrapolate regional economic trends from fragmentary textual sources, so archaeologists make suppositions on the nature of occupation at a site on the basis of finds, decorative elements, and size. A degree of luxury, decoration, or relatively large size are generally taken as indications that a landowner occupied the site, while a lack of any such elements can usually be assumed to indicate the reverse.

As discussed above, on the basis of these criteria, the villages and farmsteads of North Syria and Galilee and Samaria are thought to have been inhabited by resident landowners. In Egypt also, the rich Mareotis villas, embellished with baths, frescoes, imported marble and peristyles, have the appearance of the residences of wealthy proprietors. Textual evidence suggests that at least some of the owners were Alexandrians: papyri mention landholdings in this region belonging to a late 5th c. Flavius Maximus and Flavius Olympiodorus, both *scholastici* and advocates in the court of the *praefectus Augustalis*, and a Flavius Julianus '*notarius sacri palatii*', holding the rank of *clarissimus*.[90] The evidence of papyri indicates that such Alexandrian estate owners were highly involved in the daily management of their estates,[91] and that even members of the new imperial elite directly managed their land for commercial production, rather than leasing them, as earlier estate owners had done.[92] Judging from the quality of building and levels of luxury at the excavated villa sites, at least some estate owners must have resided for a part of the year at their luxurious lakeside estate-centres.

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[86] Banaji (2001) 174; Ward-Perkins (2000) 340.
[87] Empereur (1993) 45.
[88] Dar (1986) and (2004).
[89] Hirschfeld (1997) 43–44.

In contrast, in the Tripolitanian Gebel there seem to have been few luxurious rural villa residences.[93] Many rural sites in this region lack a luxurious residential area. At Henscir Sidi Hamdan, for example, we find a large, carefully laid-out olive farm with 9 presses, but very few residential features and no luxury elements,[94] although the size of the installation suggests that it belonged to a very large estate.[95] The larger ashlar-built farms, associated with high-ranking tombs, have yielded little in the way of decorative elements. In the absence of mosaics, wall-paintings and baths, Mattingly concludes that these were not occupied by the estate owners.[96] The sites identified as estate centres in the Kasserine and Segermes regions were also relatively simple, with modest decoration.[97] Even KS 022, which has a small bathhouse and mosaic (see above), does not seem to display the level of decoration and luxury which we would expect in the habitation of the owner of a large, commercial, oil-producing estate. Where amphora stamps are available, they show that the oil production was controlled by elite families of the coastal city of Lepcis Magna.[98] Both archaeological and epigraphic evidence suggest the existence of large, absentee estates.[99]

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[90] Haas (2001).
[91] Banaji (2001) 113.
[92] Sarris (2004b).
[93] Mattingly (1995) 141.
[94] Percival (1975) 64; Brun (2004) 193.
[95] Mattingly (1988).
[96] Mattingly (1985) and (1995) 142.
[97] Bruce Hitchner (1990); Ørsted *et al.* (1992).
[98] Mattingly and Bruce Hitchner (1993).
[99] Peyras (1975); Brun (2004) 210.

In the Methana region of Greece, we see neither a village pattern, as in Syria and Palestine, nor rich villas, as in Egypt. The settlement pattern was one of dispersed and modest farmsteads, small in size and without decorative elements, nearly all of which seem to have been engaged in commercial oil and/or wine production. A couple of larger sites, solidly built of ashlar blocks, have substantial olive-pressing installations but no decorative remains or fine pottery. These sites are reminiscent of the quality ashlar-built oil complexes with modest facilities in the Tripolitanian Gebel. The excavators similarly conclude that the land was held by elite absentee landowners, such as the occupiers of the large Late Roman villa site at Halieis, and was operated by dependent tenants.[100]

Thus, settlement evidence seems to suggest that in both North Africa and the Methana Peninsula production was controlled by absentee landlords, whereas in Egypt, North Syria and Palestine, production may have been carried out by farm owners who lived in either villages or villas closely associated with production.[101]

CONCLUSION

The data discussed above seems to suggest that screw presses were more commonly used in either a villa or village where oil and wine-making installations were associated with what appear to be the habitations of resident owners, rather than absentee landlords. This could have been one factor which influenced the tendency towards, or against, the adoption of screw technology. Installations in Tripolitania, Tunisia and the Methana peninsula appear to have been used on large estates with absentee landlords, who seem to have been less inclined to adopt changed technology. The evidence from Egypt, North Syria and Palestine suggests that production may have been carried out by resident owners—whether of large estates or small holdings—living close to their land and directly involved in the processes of production, who may have been more likely to adopt changed technology. It is certainly not claimed that this is an invariable pattern or rule, or the only factor involved. It is merely suggested that among the many factors at play—technical, geographic, cultural, chronological, environmental, and commercial—the relationship of the landowner to his land may also have played an important role.

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[100] Bowden and Gill (1997a) 81–82, (1997b) 90; Foxhall (1990) 109–11, (1997) 263–64.

[101] Monasteries also appear in late antique Palestine, including Samaria and Galilee, and screw presses have been found at the monasteries of Khirbet el-Queseir and Mevo Modi'im, for e.g.: Brun (2004) 135. The case of a monastery seems to differ from both a parcel of land belonging to a large estate which is managed by a hired agent, and from a landowner's own estate. It could be argued that the presence and interest of the monks in their land was more equivalent to the latter, however.

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PRODUCTION

CERAMIC PRODUCTION IN AFRICA DURING LATE ANTIQUITY: CONTINUITY AND CHANGE

Michel Bonifay

Abstract

This paper examines the evolution of late antique ceramic production in Africa, pointing to continuity and change in morphology, technology and economy. Throughout this period, African ceramic shapes retained Punic traits, and remained firmly anchored in Roman tradition, but also seem to have been influenced by some new Byzantine patterns. Technology did not change radically, but there were some slight changes (impoverishment?) in the production of existing objects. The most obvious changes entailed a short distance transfer of amphora production sites from city suburbs to the countryside and to town centres, as well as a long distance transfer of Red Slip Ware workshops from Zeugitana, to Byzacena and then back to Zeugitana, to the region around Carthage.

INTRODUCTION[1]

In around A.D. 350, the Mediterranean market was dominated by African ceramics. This fact was established in 1972 when J. W. Hayes published the first distribution maps of African Red Slip Wares,[2] and Cl. Panella and D. Manacorda, in chapters of the *Ostia* monographs, inventoried late antique African amphorae from the western Mediterranean.[3] In Africa, ceramic production seems to have been linked to major foodstuff production. The distribution patterns of African amphorae, mainly in the western Mediterranean, were related to the commercialisation of olive oil,[4] *salsamenta*[5] (which includes both garum and

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[1] I would like to thank Ms. Mara Coffman-McManus, a student at the Université de Provence, who kindly agreed to revise and correct the English text.

[2] Hayes (1972) 463, map 26.

[3] Panella (1973); Manacorda (1977).

[4] Carandini (1970).

[5] Ben Lazreg *et al.* (1995).

L. Lavan, E. Zanini, and A. Sarantis (edd.) *Technology in Transition A.D. 300–650*
(Late Antique Archaeology 4 – 2006) (Leiden 2007), pp. 143–158

solid salt-fish) and wine;[6] these amphora cargos were sometimes supplemented with cooking and domestic wares. On the other hand, the very wide distribution of African Red Slip (vessels and lamps, abbreviated ARS), both in the western and eastern Mediterranean, was probably also associated with the supply of corn to Rome and the provinces.[7]

This paper will examine how the industry evolved from the end of the Roman period to the Arab conquests, in terms of morphology, technology and economics.

Morphology

The morphological range of African ceramics did not change drastically during Late Antiquity. From the 5th to the 7th c. A.D., African ceramics tended to follow mainly Roman, but also some ancient Punic influences, alongside new eastern Mediterranean trends.

The Survival of Punic Characteristics

Punic characteristics, which one would expect to have disappeared after four or five centuries of Romanisation, continued to influence African ceramics. The following three examples demonstrate their persistence.

1. Amphorae of Punic Tradition

Among the different amphora groups, it is possible to pick out some with Punic characteristics. The term was first employed by F. Benoit in order to describe amphorae produced in Africa after the fall of Carthage: "dont le type obéit incontestablement à une tradition punique par l'emplacement des anses [on the shoulder not on the neck] et la forme générale [almost perfectly cylindrical]".[8] A similar shape is attested in Tripolitanian production during the first three centuries A.D.[9] More recently, several new types have been discovered, providing evidence that they were widely distributed in Roman Africa: in Sitifensis, in coastal

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[6] Lequément (1980).

[7] Bonifay (2003).

[8] Benoit (1962) 327.

[9] Panella (1973) 562–64.

Byzacena and in the northern part of the Hammamet Gulf.[10] In this last region, we are able to track production from the 2nd to the 7th c. A.D., since even at the time of the Arab conquest, Neo-Punic amphorae (fig. 1) were still being produced in the northern Hammamet Gulf.[11]

In East Mediterranean regions with a Phoenician tradition, an identical continuity can be observed: during the 7th c., when the manufacture of Greco-Roman LR amphora 1 in Cilicia had ceased, the production of the Gaza LR amphora 4 and bag-shaped LR amphora 5–6 continued in the Levant well into the Islamic period.[12] In Africa, it is difficult to trace the beginning of Islamic dominion, but we can note the persistence into modern times, of the Semitic amphora type with handles on the shoulders. The Tunisian 'sefri' (literally 'the [jar] which travels') is widely distributed throughout the Mediterranean.[13]

2. Handmade Pottery

Handmade pottery belonging to the Libyan tradition, together with Punic wheel-turned pottery, is well-known during the Libyco-Punic period, notably in the Sahel region.[14] The production included jars, polished red-slip bowls and, especially, cooking ware. Continuity of production in the Roman period is doubtful. Many sherds discovered in 2nd–3rd c. levels are probably residual.[15] This pottery, nevertheless, supplied many of the three-pinned braziers, characteristic of kitchens throughout the Roman period, particularly in Byzacena and Tripolitania.[16] In contrast, northern Tunisian braziers were usually wheel-turned.[17] Besides these braziers, it is likely that a certain proportion of Roman cooking ware in Africa was handmade, being imported from the nearby island of Pantelleria.

In the second half of the 4th c., African handmade pottery again began to play a greater role due to the influx of a new ware, characterised by a calcitic temper (designated to prevent a thermic shock) which covered the bottom of the vessels, mainly casseroles, and the underside of their lids. 'Calcitic ware' (fig. 1) appears to have replaced wheel-turned cooking ware in the 6th c., as can be seen in the Hammamet region.[18]

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[10] Bonifay (2004a).

[11] Bonifay (2004a).

[12] Sodini, Villeneuve (1992).

[13] Bonifay (2004a) fig. 18.

[14] Morel (1996–98).

[15] Van der Werff (1984).

[16] Pentiricci *et al.* (1998) fig. 10.

[17] Bonifay (2004b) 295.

3. Figurines Re-cycled by the New Religion

A great number of clay figurines, many of them depicting a mother-goddess seated in a wicker armchair breast-feeding a child,[19] which stemmed from Punic tradition, were still present in Roman times. These representations seem to have been connected with the Punic goddess, Tanit, of which the most famous example, nearly life-sized, comes from the Thinissut sanctuary.[20] Very similar objects were still produced in the 6th c. ARS workshop of Oudhna,[21] in the same fabric as ARS lamps. The moulds, like those of the lamps, were plaster.[22] However the interpretation of these artefacts may differ, taking their chronology into account, these women with voluminous hairstyles, breast-feeding children, could also be seen as representations of the Virgin (fig. 1). The Neo-Punic character of these late Vandal or Byzantine products is likewise demonstrated by other figurines that were made from the same fabric, for instance, pregnant, bare-breasted women, standing with their hands on their bellies, which are reminiscent of ancient fertility goddesses.[23]

Finally, we can find the same iconography on tiles with relief decoration, used in the decoration of Christian basilicas. Two examples, one from the region of Bou Ficha, and a similar one from Nabeul,[24] both show two women, each with a child on their knees, sitting side-by-side on two thrones. A relationship with the mother-goddesses is obvious, but they have been more credibly interpreted as representations of the Virgin.[25] The tile sizes used Punic units of measurement.

Anchored in the Roman Tradition

As far as ceramics are concerned, it was only during the 2nd c. A.D. that Africa actually became Roman: first by integrating and making

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[18] Bonifay (2004b) 305.
[19] Bonifay (2004b) fig. 243.
[20] Merlin (1910).
[21] Barraud *et al.* (1998) 154–56.
[22] Bonifay (2004b) fig. 43.
[23] Barraud *et al.* (1998) fig. 14, nr. 17.
[24] Bonifay (2004b) fig. 247.
[25] Duval (1994) 290, nr. 1.

African Greco-Italic patterns, and then by supplanting them within their own territories. The following three examples imply that, at the end of Antiquity, the Roman tradition was to some extent more vibrant in Africa than in many other Mediterranean regions.

1. Commercial Amphorae of the Greco-Roman Tradition

Amphorae of the Greco-Roman type (with handles attached to the neck, not to the shoulder) had already disappeared from most regions of the old Roman world by the end of the late antique era: production in Gaul had stopped in the 5th c., and, during the 7th c., it survived in Italy only in the southern part of the peninsula. However, we can identify a large variety of 5th–7th c. African amphorae types,[26] perhaps a greater number than in any historical period. These demonstrate two trends: one series of containers grew taller and bigger, reaching impressive capacities of up to 80–90 litres, and another became smaller, in some cases, being only 40 cm in height. But the general shape did not change; it remained a cylindrical body with a short foot and a narrow neck to which the two handles were attached.

The fact that this form, which was highly suitable for stack, survived long into the Late Byzantine period, also testifies to the continuity of old methods of shipping foodstuffs. Roman Africa was certainly familiar with transporting products like leather skins[27] or wooden barrels,[28] but the Greco-Roman clay amphora continued in use until at least the 7th c.

2. Continuity in Quality and Shapes

ARS was one of the most long-lived Mediterranean fine wares. No other amphora type could equal its homogenous quality from the end of the 1st to the middle of the 7th c. Some products of the 6th c. (e.g., those of the Oudhna workshop) are even harder to distinguish from earlier ones. The best-known ARS workshops (El Mahrine, Oudhna, and Sidi Marzouk Tounsi) are late antique in date. As a rule, the most common shapes did not change from the 4th to the 7th c., as seen, for example, in the flanged bowl series. As in the past, potters imitated metal wares. This is particularly evident in the late Central Tunisian production of the Vandal period, illustrated by Hayes' forms 82–85, with their sharp cut profiles and feather-rouletting decoration (that imitated the decoration of silver vessels). The large plates of Hayes' forms 90 and 105 may also be considered as silver plate derivatives. Finally, there is also continuity in themes, sometimes even in the way they were incorporated in decorative patterns. This becomes obvious by comparing figures of gods and goddesses on appliqué decoration of the 3rd c. with figures of standing saints (or Christ?) on stamped decoration of the 6th c.

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[26] Bonifay (2004b) 125 f.

[27] Martin-Kilcher (1998). ARS in the form of a leather skin: Carandini *et al.* (1981), Pl. CXXXIV, 5.

[28] A fair number of ARS forms reproduce the shape of a barrel: Carandini *et al.* (1981), Pl. XXIII, 6–9, 16, Pl. CXXXIII, 2, 5.

3. 'Antique' Moulded Lamps

Some antique lamp shapes (mould-made lamps, following the Hellenistic-Roman technique) survived until the 5th c., a phenomenon clearly apparent in the stratigraphy of Carthage.[29] Rounded and heart-shaped noose lamps, which had been the most common 2nd–3rd c. types, were still produced during the 4th and 5th centuries, but without slip or handle-holes, and generally without signature marks. In certain rural zones, some late antique lamp shapes remained in use until the beginning of the 6th c. The 5th to 7th centuries were also the apogee of ARS lamp manufacture. Although original, the shapes do recall earlier types, and their production techniques, involving plaster moulds, were the same. Where their decoration is concerned, gods and goddess were to some extent replaced by saints and crosses, but animals remained the preferred representation.

The Influence of Eastern Mediterranean Ceramics

On the eve of the Arab conquest, the African pottery industry seems to have lost its originality. It appeared to copy the eastern Mediterranean forms, common in much of the pottery produced in Mediterranean regions, such as southern Spain, southern Italy and the Aegean. The East, which was already under Arab domination, would preserve its tradition, which would continue to spread, up to the Arab conquest of Africa. This is illustrated by the following three examples.

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[29] Anselmino 1982.

1. Globular-Shaped Amphorae

During the 7th c., several different types of globular-shaped amphorae appeared.[30] They gradually asserted themselves among transport containers, and would live on under early Islamic domination, until at least the Aghlabid period.[31] This phenomenon is well-known in many other 7th c. Mediterranean regions. A comparison between African and eastern examples has led to the assumption that the new amphorae were used for wine-transport. In Africa, the appearance of this new wine container seems to have been the result of two different influences: on one hand, African amphorae looked to eastern types like LR amphora 1 and 2; on the other, they perpetuated the Punic-Roman tradition of water jugs with one or two handles, generally with an umbilicated base.

2. Wheel-Turned Cooking Wares

During the 5th c., wheel-turned cooking wares, which had contributed to the fame of African ceramic production throughout the Roman period, gradually made way for an increasing amount of handmade pottery, in particular, the so-called 'Calcitic ware'. From the 6th c., wheel-turned cooking wares were influenced by, or closely imitated, eastern Mediterranean shapes. This phenomenon perhaps began at the outset of the 5th c., with the appearance of a new form of globular-shaped cooking pot,[32] different from the earlier range of African cooking wares. The trend became more obvious in the 6th and 7th c. products of the Oudhna workshop: the most characteristic were kettles with a ribbed body and pinched mouth,[33] previously unknown. Finally, Carthaginian potters of the 7th c. closely imitated certain forms of Constantinopolitan cooking pot.[34]

3. 'Vandal' Wheel-Thrown Lamps in Byzantine Layers

Following an old publication of Delattre,[35] it became customary to label as 'Vandal' a group of bitronconical wheel-thrown lamps, that were produced in ARS, as well as in common buff ware. Although their chronology is not well established, it seems that the majority of lamps discovered at Carthage derived from Byzantine levels.[36] An important workshop producing a 6th–7th c. common variant was identified at Oudhna,[37] but it is unlikely that this was the only production unit. It could be possible that these African lamps derived from a range of wheel-turned lamps, which spread widely throughout the Syro-Palestinian region from the 3rd c.[38] Indeed, except for the old Punic examples, no indigenous predecessor has been distinguished.[39] The shape would survive into the Early Islamic period, until at least the 9th c.[40]

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[30] Saguí (1998) fig. 8; Bonifay (2004b) fig. 83.
[31] Ben Lazreg (2000) 73, n° 48–50.
[32] Fulford (1984), Casserole 19; Bonifay (2004b) fig. 129.
[33] Bonifay (2004b), fig. 130.
[34] Hayes (1978) 75 (XXIII, 4).
[35] Delattre (1889).

Technology

The technology of the African ceramic industry did not evolve radically during Late Antiquity. Its exceptional technological longevity is rather astonishing. Nevertheless, slight changes can be observed at the end of Byzantine period.

The Saggar Firing Technique

In Africa, Red Slip pottery production can be identified through the remains of firing tools called saggars. Saggars are cylindrical clay boxes, wide-mouthed at one end, narrower at the other, into which the pottery to be fired must have been placed. Comparison with techniques used in modern faïence workshops, suggests that saggars were stacked on top of each other, forming towers inside the kiln. They are omnipresent at all ARS workshops recognised in Tunisia: in El Mahrine,[41] Sidi Marzouk Tounsi, Henchir es-Srira, Henchir el-Gellal Djilma,[42] and Oudhna.[43] The example of Oudhna, the only ARS kiln so far excavated, indicates that inside a saggar there was room for some 12 vessels, and that approximately 180 saggars could be set inside an oven, giving a total firing load of more than 2,000 pots.

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[36] Bonifay (2004b) 429.

[37] Barraud *et al.* (1998) 154 et fig. 13, n° 14–15.

[38] Orssaud, Sodini (1997) 63–64.

[39] Bussière (2000) 127.

[40] Ben Lazreg (2000) 75, n° 56–57: wheel-thrown lamps from Raqqada.

[41] Mackensen (1993).

[42] Peacock *et al.* (1990).

[43] Barraud *et al.* (1998).

In Gallic Sigillata workshops, the separation of flames and smoke from pots was accomplished by the use of clay pipes. This was exactly the opposite to the African way of firing, in which pots, instead of smoke, were enclosed. The result however was the same: saggars protected the vessels and provided an oxidising atmosphere throughout the firing process. Muffle furnaces (where no contact occurred between ceramics and flames) started to disappear from Gaul in the 4th c., whereas in Africa, the technique survived until the 7th c.

At the end of the 7th or perhaps the beginning of the 8th c., evidence for technological impoverishment can be detected. In Nabeul and Sidi Jdidi, some sherds of Hayes' form 105 plates, one of the last forms to be produced, possessed a bad adherent brownish slip, sometimes with black marks, and a fabric that was brown to white in colour. Thus, at this stage, the use of saggars was clearly abandoned and the firing of African 'Red' Slip Ware was no longer controlled.[44]

Changes in Lamp Manufacture

Unlike the majority of Mediterranean and North European workshops, which used clay moulds to produce lamps, African potters used moulds made of plaster. These are simple to use, but wear away rapidly.[45] They were adopted both by Early and Late Roman workshops, but most known plaster moulds were designed for ARS lamps of the 5th and 6th centuries (Hayes' types I and II). The manufacturing processes of these lamps, described in detail by M. Mackensen, comprised the modelling of a plain clay archetype and its decoration with appliqué, after which this archetype would be used to produce the definitive plaster moulds.[46] From the second half of the 6th c., this sophisticated process was progressively abandoned. The very blurred decoration of Hayes' type II lamps must have been caused by continuous use of old moulds, or new ones moulded on old products.

At the end of the 7th c., a new decorative style with linear and rather naïve patterns appeared.[47] Motifs seem to have been hand-designed directly in the mould, which implies that the moulds were no longer plaster but ceramic.[48] One example was unearthed in Rougga (Bararus), together with sherds of coarse ware and Hayes' type II lamps. Perhaps this change was not only due to technological impoverishment, but also to the influence of other Mediterranean industries, such as the Syro-Palestinan and Sicilian lamp-making industries.

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[44] Bonifay (2004b) 65 et fig. 111.

[45] Bonifay (2004b) 81.

[46] Mackensen (1993) 101–105.

[47] Bonifay (2004b) fig. 231.

Changes in Fabric Colour

Roman African coarse ware is well-known for its white external wash and red-brick fabric. This peculiar composition resulted from mixing salt water with clay, rich in iron oxides,[49] as is done today in modern Tunisian workshops. Some African potters added salt to the water or the clay, while others used seawater, which was transported to them in cisterns. At the end of the 7th c., a white-in-section colour seemed to become the African norm.[50] This was first observed on the latest dated amphorae finds, but it is also obvious in the common ware. Workshops built during the 7th c. in the centre of the city of Nabeul produced small white jugs with a ribbed body. Furthermore, the evolution towards white fabrics is also noted in the brown-slipped ARS mentioned above.[51] A technical explanation is not easy to find. One possibility is that it stemmed from the use of a more calcareous clay at this stage, or a different method of firing, perhaps combined with the use of salty water.[52] Whatever the case, the presence of white-in-section fabric is interesting because it pre-figured a common Islamic practice: in the 9th c., all coarse ware at Oudhna or at Raqqada was white-sectioned.[53]

Economy

The most visible evolution in African ceramic production during Late Antiquity concerned its geographical setting. A movement of ARS workshops back and forth between northern and central Tunisia is clearly discernable from the 1st to the 7th c. In addition, the 5th to 7th centuries also saw a series of short-distance movements of amphora and coarse ware kiln sites.

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[48] Bonifay (2004b) 81.
[49] Peacock (1984).
[50] Bonifay (2004b) 73.
[51] Bonifay (2004b) 65.
[52] Information Claudio Capelli.
[53] Information Soundes Gragueb.

Long-Distance Transfer of ARS Workshops

It appears that from the end of the 1st c. A.D., the production sites of ARS, alternated frequently between northern and central Tunisian workshops. Even if earlier production units have not yet been discovered (Lamboglia's '*sigillata chiara* A'), it seems that until the end of the 2nd c., the most active kilns were situated in northern Africa Proconsularis, perhaps in the vicinity of Carthage.[54] In the 3rd c., a new wave of production took over, originating in central Byzacena (Lamboglia's '*sigillata chiara* C'). At the beginning of the 4th c., northern workshops, in particular El Mahrine, regained their importance and exported throughout the Mediterranean. The middle of the 5th c. saw another shift: the most characteristic ARS of the Vandal period was produced by units in central Byzacena (Sidi Marzouk Tounsi), after which those of the Carthage region recovered their hegemony in production and trade. This took place in the period between the Justinianic and Arab conquests.

How does one explain these long-distance transfers in production sites? The development of ARS workshops in central Byzacena (Lamboglia's category C) has been linked to olive cultivation, which could be considered to be the driving force behind the production and trade of ARS.[55] Two initial objections can be raised: olive oil was not the only product transported in African amphorae, and the use of ARS to carry foodstuffs was not really seen before the 5th c. What is more, the region where ARS was produced (the eastern region of Kairouan) grew cereals as well as olives. Perhaps we can interpret the emergence of ARS workshops in the Mejerda valley (Lamboglia's category D) from the second quarter of the 4th c. in the same way, since soils irrigated by the Mejerda river were even better suited to the cultivation of corn. Finally, one should note that the creation of these workshops, the largest in the history of ARS production, coincided with the growing dependence of the western provinces on the African corn supply. After all, the foundation of Constantinople had caused the diversion of the Egyptian trade.[56] On the other hand, the movement of production to central Byzacena in the second half of the 5th c. might also be linked to altered political circumstances. The religious persecution of the Catholic population and the confiscation of the land by the new ruling class in the Vandal territory (northern Tunisia) are today considered to have had devastating effects, and may have been associated with this movement.[57] The end of the 5th or the beginning of the 6th c., prior to the Byzantine re-conquest, seems to have marked a return to the earlier situation, and northern workshops prospered once again. The most important ones are now no longer situated in the Mejerda (El Mahrine), but in the Oued Miliane valley (Oudhna), as shown by the Carthage excavations. Workshops around this city were apparently the last ones to produce and export ARS, up until the end of the 7th or the beginning of the 8th c.

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[54] Oudhna could be a good candidate: Bonifay (2004a) 47–8.

[55] Carandini (1970).

These long-distance transfers of workshops also imply the transmission of knowledge. M. Mackensen has underlined the links between central Tunisian products and the decoration and shapes of the first El Mahrine ware.[58] The same observation can be made at the workshop of Oudhna, which, at the end of the 5th or the beginning of the 6th c., came under the influence of those at Sidi Marzouk Tounsi.[59] In this case, one can imagine that a re-location of both workers and apparatus will have taken place.

Short-Distance Transfer of Amphora Workshops

Throughout the Roman period, two types of amphora workshops seem to have co-existed in Africa. The first type of workshop, perhaps not the most important, was rural, linked to great estates and situated mainly in the African interior. The second type was located on the outskirts of towns, like *Sullecthum* or *Leptiminus* in Byzacena, with the town name sometimes occurring on stamps.

The Salakta survey, conducted 20 years ago, showed that amphora workshops in the 5th c. moved from the suburbs of the city towards more rural, landlocked areas. This could have corresponded with a re-organisation of industry under Vandal domination.[60] However, now, this model must be slightly tempered. Firstly, the re-location is not firmly dated: certain amphora types (Keay 62), which, in 1984, were dated to the middle of the 5th c., are now dated to the 6th c. Secondly, the transfer distance was not very great: only 5 or 6 km separated the Salakta suburbs from the late rural amphora workshops. Similar observations have been made by a survey undertaken in the territory of Nabeul. The Roman production units in this territory were situated quite far from the city, set at the foot of hills with abundant clay deposits. But in Late Antiquity, we can observe a shift to an area some 5–6 km to the North-East of the city, located at an equal distance from the sea.[61]

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[56] Bonifay (2003).

[57] Modéran (2002).

[58] Mackensen (1993) 469.

[59] Bonifay (2004b) 484.

How can one explain these short-distance transfers? Th. Peña[62] suggests that the transfer of Salakta's suburban production centres towards rural areas during the 5th c., may indicate the end of the annona system of olive oil movement, which had operated up until this time: *ostraca* from Carthage make clear that, at the end of the 4th c., olive oil from the interior of Zeugitana was transported in leather skins, poured into locally-produced terracotta amphorae, and shipped overseas. Vandal invasions ended the *annona* and so disrupted these movements. Th. Peña proposed to transpose this model, using as additional evidence the fact that the amphora industry in Salakta's suburbs came to an end at the moment of the Vandal conquest. But at Nabeul it is also possible that there was a connection between the transfer of workshops and a re-location of foodstuff production centres, which needed amphorae to market their produce. We can witness a gradual movement of the preparation of *salt-fish* products from the city centre to the northern Nabeul coastline, probably before the Vandal period. The new location could have been favoured because of the proximity of lagoons which could be used as fish ponds or salt flats. One cannot exclude a transfer of harbour installations from *Neapolis* to another coastal shelter site (Maamoura), which was closer to the manufacturing units.[63]

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[60] Peacock *et al.* 1989.
[61] Bonifay (2004b) 483.
[62] Peña (1998) 213.
[63] Bonifay (2004b) 484.

Ceramic Workshops in Town Centres

The final move of amphora workshops in the Nabeul region was once again towards the city, in the second half of the 7th c. However, the production units were no longer confined to the *pomerium* as in Roman times, but now entered the town itself. For instance, in *Leptiminus*, an amphora workshop was installed in one of the public baths, which by this time had been abandoned.[64] Recent excavations by Latifa Slim in the 'Maison des Nymphes' insula of *Neapolis*, have revealed production evidence for late miniature '*spatheia*' in white-sectioned fabric,[65] while comparable coarse wares, for instance, small jugs with a ribbed body, were also present. These units were installed in the ruins (?) of urban houses, and co-existed with other craft production units, e.g., those used for lime-burning.

Unlike amphorae and coarse ware, the 3rd and 4th c. ARS industry seems to have been tightly connected with large rural estates. ARS workshops linked to cities are currently considered to be a later development, as the situation of the 2nd c. A.D. is not yet known. This is the case with Oudhna and perhaps also with Sidi Khalifa. In Oudhna, an old bath building, the so-called 'thermes des *Laberii*', was re-used. This introduction of the pottery industry to city centres is a well-known Byzantine phenomenon and prefaced a situation that would become more common during the Islamic period.

Conclusion

From A.D. 350 to 699, the characteristics of the African pottery industry did not change fundamentally, maybe because of unaltered demands. Throughout the period, vitality of production and technology was sustained by economic growth and the mobility of workshops. Nevertheless, around A.D. 650 some changes in technology became apparent, although they were slow (in ARS), slight (for lamps), or hard to explain (in colour of fabric). In some cases, we must accept a certain impoverishment of technology. A true technological turnaround did not occur until the 9th c., when glazed wares appeared. So, for Africa, as for many other parts of the Mediterranean, the question is: "what did indeed happen during the 8th c.?"

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[64] Stirling (2001).

[65] Slim, Bonifay and Piton (2002).

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FORM, FUNCTION AND TECHNOLOGY IN POTTERY PRODUCTION FROM LATE ANTIQUITY TO THE EARLY MIDDLE AGES

Paul Arthur

Abstract

This article discusses the development of ceramic technology from the 4th to the 8th c. A.D., in both the East and West Mediterranean areas. It outlines the competence of Late Roman ceramics, dominated by African producers, with some evidence of innovation in decoration in the West. Change occurs from the 5th c. onwards, in different regions at different times, connected to the dislocation of markets and the end of large scale production. Large areas of the North return to the local production of hand-made pottery, whilst in the Mediterranean wheel-thrown pottery also becomes cruder. Continuity is greatest in the Levantine regions under Islam, though not in Africa. However, innovations are still known, including *clibani* and the use of glazes.

Turn, turn, my wheel? Turn round and round
Without a pause, without a sound:
So spins the flying world away!
This clay, well mixed with marl and sand,
Follows the motion of my hand;
For some must follow, and some command,
Though all are made of clay!

Stop, stop, my wheel! Too soon, too soon
The noon will be the afternoon,
Too soon to-day be yesterday;
Behind us in our path we cast
The broken potsherds of the past,
And all are ground to dust at last,
And trodden into clay!

from *Keramos* (1878) by Henry Wadsworth Longfellow

It is now hard to doubt that, throughout Europe and much of the Mediterranean, the end of Antiquity witnessed a substantial decline in the use of material technology. The decline, however, was not absolute, nor, indeed, did it occur everywhere at the same time. Furthermore,

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it is still debated how much the decline was a question of quantity as opposed to quality. Indeed, it may also be questioned if the available evidence indicates a generalised loss of technical and technological know-how, or rather a technology transfer to other areas and cultures or to the surviving elite, whether lay or ecclesiastical. As is often the case, the answer probably lies between the two. For instance, in some spheres, such as that of water management, for aqueducts and hot baths, it is now fairly clear that a certain measure of survival was due to the transference of technology to the Islamic world during the 7th and 8th centuries. In northern Europe, similar processes may have survived within Merovingian and Carolingian society.

Studies of the survival or decline of ancient technology would not be complete without taking into consideration the story of such a humble and ubiquitous material as clay, and examining how it was used for the production of ceramics through late antique and Early Medieval times. Indeed, through the study of "the broken potsherds of the past", we can attempt to examine man's response to the shrinking horizons provided by a fragmentation of the Roman world system into smaller geopolitical and economic units. Conversely, through pottery, we can also envisage the appearance of new cultural areas that have to do less with political frontiers drawn across the ancient map and, perhaps, more to do with adaptation to the changing conditions and resources afforded by the diverse natural regions that made up Europe and the Mediterranean. To extricate the interrelations between politics, economy, social and cultural mores, and the potentials and restrictions of the environment, is an exceedingly complex task. Together, however, such factors make up the rich fabric of the past that is reflected in the archaeological assemblages of material culture.

Though studies of late antique ceramics have gone a long way since John Hayes launched his seminal study of Late Roman pottery in 1972, there is still an enormous amount of work to be done. Coming from a 'post Romano-British background' (as Mortimer Wheeler apparently remarked of British scholars who had left Roman Britain to work elsewhere), my perspective of ceramic studies is rather conditioned by what has been achieved in the UK, an area little 'hampered' by astounding classical remains such as are found in the Mediterranean. This paper, however, will take a Mediterranean and European-wide view. It will attempt to identify and explain some of the changes in ceramic culture and technology between Late Antiquity and the Early Middle Ages. It is addressed primarily to an audience of scholars interested in what archaeological evidence can potentially tell us about material culture. Indeed, it examines questions that I feel may be usefully researched and discussed within the broader framework of the transformation of the late antique economy and society and the emergence of a new, post-classical, world.

Late Roman Ceramic Production

Pottery produced in Late Antiquity was, on the whole, of good quality, differing little from that made during the Republic and Early Roman Empire. Clays were often carefully worked, according to needs. Vessels were usually well-turned and fired, and sometimes decorated with applied, moulded, stamped or painted decoration, with slips, and occasionally with lead glazes. Some geographical areas specialised, such as the Tunisian area of North Africa. Here the exportation of agricultural produce stimulated ceramic manufacture and trade, almost leading to a monopoly in the manufacture of fine tablewares. Coarse and cooking wares produced for local and regional markets were produced alongside tableware that was exported over hundreds of kilometres from workshops sited principally in North Africa, but also in western Asia Minor, in Cyprus and Egypt. Practically the entire gamut of techniques known in earlier Roman times was still employed for the manufacture of pottery throughout most of the Mediterranean, well into the 6th c. and, in a few areas, well beyond that time. One might make a case for a decrease in the use of moulded and an increase in the use of painted decoration. Moulded decoration was typically found on fine tablewares produced in Italy from the 1st c. B.C., often in imitation of metal prototypes, particularly on the so-called Arretine wares from Arezzo and elsewhere, which were widely exported to the provinces. By the 2nd c. A.D., the manufacture of these Italian tablewares had mostly given way to the production of numerous provincial copies, often quite devolved, but nonetheless, of quite fine quality.

Indeed, after the decline of the best Italian fine wares, those manufactured in North Africa and Asia Minor virtually monopolised tables well into the 6th c., through the two predominant classes, known respectively as African Red Slip Ware (abbreviated as 'ARS') and Phocean Red Slip Ware (Late Roman C). The former supplied much of the Western Empire, though was scarce in northern Gaul and Britain, probably because of the costs involved in overland transportation. The latter, instead, dominated much of the Mediterranean and Black Sea regions from the Adriatic eastwards. The ubiquity of these ceramics, in turn, gradually set the pattern for numerous imitations, even back in Italy, which rarely achieved the quality of the originals.[1] This may be explained by the fact that the ceramics from Tunisia and Asia Minor were manufactured in large professional workshops that some scholars qualify as industrial, given their substantial workforces, their instruments and a probable division of labour.[2] Indeed, the high levels of standardisation of the various types of vases are telling, as can be seen in the typologies published by modern scholars that bring to mind sales catalogues of 19th and 20th c. industrial ceramics.[3] Of course, the Roman production centres did not rely on the machinery available since the industrial revolution nor, apparently, did true factories exist. Large-scale manufacture may rather have relied on concentrations of cellular ateliers, as Jeroen Poblome has argued for the relatively restricted output of the town of Sagalassos in western Asia Minor.[4]

Imitations of the major Red Slip Wares were produced over wide areas, in places such as Italy, Greece, the Balkans and the Black Sea region. Unlike North Africa and Asia Minor, most of these appear to have been produced in small workshops where expertise and technological outlay appear to have been more limited. Furthermore, in many of these smaller workshops pottery production may have been largely seasonal, with the rest of the year being devoted to agricultural matters or even to the marketing of the ceramic products themselves. On the whole, however, such centres catered for restricted local or regional markets. Amongst the better-known workshops of this type are those sited in southern Italy, at Calle in Basilicata, and at various sites in the ancient *ager Falernus* region of northern Campania.[5] Both areas produced imitations of African Red Slip Ware alongside cooking pottery, mainly from the later 4th until the first half of the 6th centuries, also bridging the transition between the Late Roman and the Ostrogothic political domination of Italy. A similar pattern is now coming to light in Apulia, where recent archaeology is helping to define a pattern of late antique ceramic production.[6] The imitations or derivatives of Red Slip Ware differ from their prototypes in their lesser degree of standardisation, lower firing temperatures, thicker walls and coarser clays and inferior slips. The slips were often not uniformly applied, thus giving a mottled appearance to the finished products. All in all, the quality of the pottery was lower than that of the North African originals, though comparable to ceramics produced throughout much of the rest of the empire and generally similar to much that had been seen since the Early Imperial period. Nonetheless, what is perhaps most striking is the fact that a certain typological uniformity was achieved throughout much of southern Italy and Greece, despite the fact that the vessels were apparently produced in numerous unrelated ateliers.

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[1] Fontana (1998).

[2] Peacock (1982).

[3] Hayes (1972).

[4] Poblome, Bes and Degryse (2005); Poblome (2006).

[5] Arthur, De Mitri and Lapadula, forthcoming; see also Freed (1983); Di Giuseppe (1998).

In Late Antiquity, ceramics decorated with broad painted swathes or finer geometric schemes became increasingly common throughout the West, gradually replacing vases with overall slips. Roman Britain, for instance, is known for a number of manufacturing sites, from Oxford in the South to Crambeck in the North, which, in the 3rd or 4th centuries, produced wares with white or red slip-painting.[7] Somewhat similar ceramics were produced in the Rhineland and in Gaul.[8] In Italy, the taste for painted pottery appears to have developed during the 5th c., to become increasingly more common in the 6th c.[9] Many products bore very simple patterns, though some, such as those in the Abruzzi, were quite articulated and relied on different colour schemes.[10] Looking eastwards from Italy, painted wares also appear to have become increasingly more common in parts of the Balkans, in Greece and in Asia Minor, as well as at Carthage to the south, thus adding to the traditional painted wares already in vogue in the Levant and Egypt. Some were similar to the painted ceramics that characterised central and southern Italy, such as the vases found at Athens and Delphi,[11] whilst others became much more elaborate (see below). To the technological prowess of Roman potters throughout the empire, new stylistic composition was now added. It may be remarked, however, that the floral and geometric compositions of the Roman potters of northern

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[6] Leone and Turchiano (2002).
[7] Young (1977); Fulford (1975).
[8] Göse (1976).
[9] Arthur and Patterson (1994).
[10] Staffa (1998).
[11] Athens: Robinson (1959) M362; Delphi: Pétridis (1997).

Europe (and later the East) were frequently far more imaginative than the plainer abstract swathes of coloured slip added by many of their western Mediterranean counterparts.

However, in the North, most of the ceramic 'industries' disappeared rapidly after the withdrawal of Rome in the early 5th c. A.D. In the western Mediterranean, instead, the majority of the major production sites seem to have essentially closed down during the course of the 5th or the first half of the 6th c. The general disappearance of large-scale production in both areas coincides, not only with the migrations, but also, and perhaps more significantly, with the main period of urban shrinkage or abandonment, and rather suggests that the changes were in some way related. When towns declined, the markets declined with them and the essentially rural-based ceramic 'industries' presumably became un-economic for professional potters to maintain. Much of the empire had already shown a phase of economic regression in mid-Roman times, and this must have stimulated the tax reductions on various industries, including the ceramic sector, seen under Constantine in the early 4th c. and, probably also, under his successors.[12] But any relief appears to have been relatively short-lived and, of course, did not survive the collapse of the empire.

Though the siting of professional potteries depended on the location of the basic raw materials (clay, wood, water, etc.), it was also essential that large markets would be readily to hand by means of an efficient (Roman) communications network. However, the collapse of many pottery industries is probably to be explained not only by a cessation of demand (though demand presumably diminished with diminishing population levels) and by rising marketing costs, but also by internal production costs. As population levels dropped and intensive agriculture diminished, agricultural surplus became evermore restricted and more highly valued as an exchange commodity. It would, therefore, be used primarily for exchange with money to pay taxes or for exchange with other basic goods. Pottery could, instead, be made by the 'household' or by a 'household industry' for group use. This seems to be a pattern that emerges with the development of the earliest village communities after Antiquity (see Peacock (1982) for the use of these terms). Only more complex communities, such as those surviving in large towns, could support a full-time workforce devoted to non-agricultural pursuits.

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[12] Jones (1964) 862.

Nonetheless, the continuity after the early 6th c. in some of the types of Late Roman vessels and in the use of slip coatings, however limited, may be an indication that some professional potters of the Late Roman industries remained engaged in the craft, even though the greater part may have turned to full-time agriculture. Continuity, such as that found in ceramics catering for the populations of such large towns as Rome and Constantinople, might signify not only generational continuity amongst potters, but also the desire to provide vessels that were linked to traditional, generally classical, eating habits.

However, evidence for these industries does not generally run past the 6th or 7th centuries. In Italy, it stops, in most areas, with Justinian's re-conquest of the peninsula. In the Spanish peninsula and in Greece, the time-scale is similar. In Tunisia, the ceramic industries collapsed later, with the Arab invasions. In Anatolia, they perhaps disappeared with the arrival of Persians and Arabs. Nonetheless, such major traumas can only have provided the *coup de grâce* to a pervasive market system that had been deteriorating steadily from the 4th c. There can now be little doubt that after Late Antiquity, pottery production catered to new market forces.

Quality Decline—1. Hand-Made Ceramics

The late antique artistic flurry in ceramics was soon to come to an end in the West and North, often apparently in the wake of barbarian invaders or putative attempts at re-conquest. Indeed, in general, pottery produced in old Roman areas declined in quality, both decorative and technological. This is immediately apparent in the former northern provinces of the Empire, such as Britain and France, where traditions of finely-potted and highly-decorated tableware very quickly disappeared after the 4th c.

Some areas even moved back wholly or in part to pre-classical traditions of hand-turned vessels. Britain, whilst still part of the Roman Empire, witnessed a gradual resurgence of hand-made pottery from the late 3rd c. onwards, both in the South (e.g. Arthur and Whitehouse (1978)) and in the North (the burgeoning of Yorkshire calcite-gritted ware). Hand-made pottery was then to predominate throughout the country during Anglo-Saxon times and, as Bryan Ward-Perkins has pointed out, even characterised the royal site of Yeavering, where one might expect to find refined artefacts.[13] Hand-made ceramics also re-appeared in south-eastern Spain in the 5th c.[14] Further east, in Albania and parts of Greece, at least in the later 6th c., as well as in Cyprus from the 7th c. (see below), hand-made ceramics also made their appearance, despite continuity in the production of wheel-turned wares. In many regions, this trend appears to roughly coincide with the appearance of peoples from northern Europe or the steppes, such as the Anglo-Saxons, the Slavs, the Lombards and the Visigoths. Indeed, many archaeologists have linked the hand-made or slow wheel-turned pottery found in Greece to the historically-documented appearance of the Slavs, for which reason it has been termed 'Slavic Ware'.[15] The trend in Romania was to read contemporary wheel-made and hand-made pottery as distinct ethnic indicators, the former being Romance (of Roman tradition) and the latter Slav. Thus, various scholars have seen the appearance of hand-turned pottery as being generally a feature of areas where the impact of migrating peoples from North Europe and the steppes was stronger. However, in Romania, some of the hand-made vases replicated traditional wheel-turned shapes, rather suggesting that both reflect nothing more than technological capabilities.[16] The use of hand-turned vessels also increased in old Roman North Africa, where it could be theoretically linked to the arrival of Berber communities. All in all, hand-turning often appears to be roughly contemporaneous with the arrival of nomadic or semi-nomadic peoples around the Mediterranean basin and particularly in western Europe; people for whom it would have been inconvenient to possess and transport the potter's wheel or to erect sophisticated kilns. Indeed, this may often have been the case.

However, if hand-made ceramics achieved some popularity in certain territories, one would also have to explain the disappearance of traditional potteries that made use of the wheel in those same areas. This is harder to explain simply by the influx of new peoples, who rarely purposely destroyed previous populations and traditions. It might be the result of a substantial decline in demand for professionally produced pottery. To this last factor, we might further add changes in food and eating habits influencing the preference for new ceramics. However, it may be recalled that the practise of making ceramics without the use of the wheel was not totally unknown to Rome. This can be seen in the output of the island of Pantelleria from Early Imperial times, as well as in hand-made products from Sardinia and North Africa.[17] Admittedly, Pantelleria may not have been the most hospitable place in the Mediterranean, with a rather conservative local economy, but it happened to lie upon a major maritime route from North Africa to Italy, and its heat-resistant hand-made pottery seems to have found favour over an astoundingly large area.

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[13] Ward-Perkins (2005) 105.

[14] Gutiérrez Lloret (1988).

[15] However, see Vroom (2003); Curta (2001) 233–34.

[16] See the discussion by Teodor (2005) 210–24.

Indeed, recent research has stressed that the simple equation 'hand-made pottery = barbarian invaders' is not quite as straightforward as may be supposed, as more refined archaeological chronologies do not always quite fit the historical evidence for migrations and invasions. The interesting studies of Cyprus by Marcus Rautman rather suggest that hand-made ceramics, which co-existed with wheel-turned pottery on the island, rather represent other, more complex, features of the disruption of the ancient world, rather than simply that of 'barbarian' invasion.[18] His view, in a nutshell, is that the 'new' ceramics provide evidence for the re-emergence of traditional household production, particularly in rural communities, with the gradual slackening or breakdown of ancient exchange networks and the increasing need to rely on self-sufficiency. His arguments may well be correct for certain areas of the former Roman Empire.

Nonetheless, despite Rautman's convincing case, it would be rash to totally exclude any influence of invading peoples in the return to hand-made ceramics in western Europe and the Mediterranean (see, for instance, Britain). The two explanations should, at least in certain parts of the old Roman world, be measured against each other. Italy appears to present a case in point. Along with Helen Patterson, I have advanced explanations similar to those of Rautman, for the simplification of wheel-turned pottery produced in Early Medieval times in central and southern Italy.[19] In this latter area, hand-made pottery was almost always absent and wheel-turned ceramics continued to be manufactured. However, vases were not always well-fired and decoration was often simpler than that witnessed in Roman times, with slip and painted embellishment often very basic, and in some cases downright sloppy.

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[17] E.g. Peacock (1982); Reynolds (1993).

[18] Rautmann (1998).

[19] Arthur and Patterson (1994).

The general pattern of central and southern Italy contrasts with the discoveries from the cemetery of Vicenne (Bojano) in central Adriatic Italy, where, alongside a painted jug, various hand-made cooking pots were found. This element might be explained by the particular nature of the cemetery which seems to have catered for the burial of an early and 'traditional' group of Lombards, perhaps semi-itinerant, who were put to rest with their horses.[20] Other examples of hand-made pottery in central and southern Italy are hard to find. At Vacchereccia in Molise, three separate fabrics were identified amongst the hand-made sherds. Though forms were very fragmentary, they included a *testum* or baking-pan, a foot-ring base and possibly other pieces that appear to have imitated Late Roman wares, presumably not long after the Late Roman workshops stopped supplying the area after the early 6th c.[21]

For northern Italy, Giampietro Brogiolo and Sauro Gelichi have stressed a very gradual change in ceramics over a prolonged period of time, which appears to contrast with more marked changes that took place in other areas of the Mediterranean.[22] Indeed, it may be that in much of the northern part of the peninsula a strongly ruralised Roman countryside transmitted its alimentary and culinary customs, with their associated ceramics, into the Early Middle Ages, through a rapid and marked ruralisation of the urban economies. Indeed, writing of northern Italy, Clementina Panella speaks of a "*precoce ruralizzazione dell'economia, conseguente all'isolamento in cui venne a trovarsi anche a seguito dello stato di guerra che per un centinaio di anni caraterizzò i rapporti con i territori rimasti sotto il dominio imperiale*" (Panella (1998) 819). With the arrival of the Lombards in the peninsula in A.D. 568 came a distinctive class of burnished pottery with stamped decoration, which is also to be found in Lombard and Gepid areas of central Europe.[23] After the first generation or two of Lombard occupation of northern Italy there is a noticeable change. The familiar mix of imported pottery types and ceramics representing the tail-end of finer late antique productions disappear, except in areas showing significant urban continuity. Thus, in the town of

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[20] Genito (1988).

[21] Patterson (1984), 166–68 and 171.

[22] Brogiolo and Gelichi (1996) 7.

[23] Cf. Curta (2001).

Brescia, the same production site appears to have produced 'Lombard' pottery and African Red Slip ware derivatives side by side.[24]

Afterwards, according to archaeological contexts, fine wares and decorated wares decline substantially, giving way almost exclusively to cooking wares, presumably once accompanied by tableware made of alternative materials such as wood. The cooking wares, like those of much of the Dalmatian coastlands, and even of Greece, where they have often been identified as products of Slav invaders, are characterised by roughened external surfaces.[25] Such surfaces were often purposely produced by tight wheel-turned grooving or rilling and incisions, or by the use of combs. This type of surface treatment recalls the more irregular surfaces of pots fired in clamp or bonfire kilns, in which vessels were imprinted by having been wrapped in grass or hay: and perhaps these provided the inspiration for skeumorphic decoration.

This monotony in the quality and style of North Italian ceramics after Rome certainly appears to add weight to Ward-Perkins' statement that "this picture of decline in the manufacture and availability of pottery is placed in sharp relief by the totally different story of what happened in the 5th and 6th c. East".[26] However, the picture is not quite so clear cut, and hardly embraces central and southern Italy or North Africa.

Quality Decline—2. Wheel-Turned Ceramics

If we look at the more central areas of the old classical world, changes in pottery manufacture and technology in Late Antiquity are still quite evident, though usually less pronounced, than in the old northern provinces. Though I have earlier referred to hand-made pottery from Cyprus, the island also provides one of the best published kiln sites from Early Byzantine times, producing items turned on the potters wheel. Hector Catling, the excavator at the relatively large production complex found at Dhiorios, remarked of the products that the "quality of this material shows a marked deterioration", with ceramics showing "thicker walls and clumsier finish", together with a "higher failure in firing", when compared to earlier times.[27] He dated the latest finds from the site to the 7th c. A.D., though their similarity to material found in Late Roman contexts at Paphos suggests that they should be dated earlier (*ex inf.* John Hayes). The island, however, continued to produce Cypriot Red Slip Ware, which catered for an inter-regional market. So Cyprus, at one and the same time, produced quite well-potted table wares, as well as coarser domestic wares and even hand-made pottery. The pottery from Dhiorios appears somewhat similar to the ceramics produced at Hierapolis in Phrygia through the 5th and 6th centuries, now known through the excavation of kilns and waster deposits located around the agora.[28] The quantity of waste appears to have been substantial. Products were thick-walled and, at most, decorated with combing, whilst finer table wares reached the town from other areas of Asia Minor. Indeed, Red Slipped Wares of quite varying quality continued to be produced not only in Asia Minor and Cyprus well into the 7th c., but also in Egypt and Greece, not to mention Tunisia. Their markets, nonetheless, declined with respect to the 6th c., being ever more limited to specific sites including major cities (e.g. Rome, Naples, Carthage, Constantinople), Byzantine *castra*, some monastic sites or high-status settlements. The presence of African Red Slip platters and small North African *spatheia* (a type of small transport amphora) in late 6th c. Lombard cemeteries in central Italy is telling.[29] African Red Slip Ware went rapidly out of production a century later, following the Arab invasion of North Africa and the Levant.

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[24] Brogiolo and Gelichi (1996) 224.

[25] Curta (2001) 233–34.

[26] Ward-Perkins (2005) 107.

Per contra, in the 6th c., new wares with quite elaborate abstract, floral and bird-like painted decoration, had been added to the repertoire of potters in Greece[30] and Asia Minor (the so-called 'Monastic Ware' at Alahan, Turkey).[31] At Gortyn on Crete, archaeologists have shown the continuity of production of this class of pottery well into the 8th c.[32] The use of such careful painting was a novelty in many eastern areas, though had precedents in Palestine and in Coptic Egypt. Even Carthage, which looked increasingly to the East following the Justinianic re-conquest from the Vandals, seems to have possessed a limited output of painted wares already from the later 5th c.[33]

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[27] Catling (1972).

[28] D'Andria (2003) 92–93: Cottica, in press.

[29] Baldassare (1977).

[30] Hayes (1972) 413; Pétridis (1997) for the proposal of production at Néa Anchialos.

[31] Gough (1985).

[32] Vitale (2001).

In parts of the Balkans and Italy, far less imaginative painted wares than those to be found in various parts of the East became common from the 6th c. and inaugurated a tradition that has survived into modern times. Furthermore, "the south Italian (and Roman) tradition of painting pots was initiated north of the Alps in about 800",[34] perhaps representing some form of technological feedback through northern Europe's political expansion southwards, into the Mediterranean in Carolingian times. Indeed, the decoration of these latter wares bears a striking similarity to the relatively simple painted decoration of Italian painted pottery.[35]

The production of quite well-produced pottery in the eastern Mediterranean into the 7th c., even if somewhat clumsier than earlier products, does seem to align with other evidence that suggests that economic decline arrived in the East later than in the western Mediterranean.[36] For instance, the use of foot-ring bases, common to Roman table wares, both eastern and western, disappeared throughout the Mediterranean, though in different places at different times. Apart from Tunisia, where African Red Slip Ware prolonged Roman tradition, foot-ring bases generally disappeared in the West during the course of the 5th c., to survive in the East well into the 7th c., never disappearing in Constantinople and its environs. This feature was probably related to the manners of "at table". Its disappearance in the West can be related to the lesser use of flat surfaces in the Early Middle Ages. Similar reasons may lie behind the appearance of either sagging or rounded, as opposed to flat, bases in cooking wares, which are further discussed below.

On the whole, in the West, including much of Italy, the pattern of production reveals a less precise or careful manufacture of pottery in Late Roman times, when compared to both earlier times and to the East, even in fairly large production sites that catered to regional markets. A further and more striking regression in ceramic technology throughout the Italian peninsula occurred from the second half of the 6th c., when output seems to have been increasingly directed to more limited local demand. The lesser care in clay preparation and less diligent (or less professional?) potting, may have been coupled with lower firing temperatures, perhaps reflecting the employment of simpler, less permanent kilns. Unfortunately, few Early Medieval kilns are known to support this idea. The three 8th c. kilns excavated at Otranto were still of Roman type and were fairly elaborate structures, though Otranto remained part of the Eastern Empire into the 11th c. They were circular in plan, varying in diameter between 2.5 and 3.5 m, and were constructed of stones and tiles bonded with clay.[37] They were used to produce small transport amphorae, up to about 50 cm in height, with carrying capacities of up to 23.4 litres, as well as cooking pots, jugs, lamps and even a few lead glazed vessels. A certain amount of selectivity in clay fabrics for various products seems also to have taken place, but they all appear to have been uniformly treated in the kilns, and display a standard reduced red-brown or dark grey fabric.

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[33] Fulford (1984).
[34] Hodges (1982) 155.
[35] Gentili (1988).
[36] Cameron (1993).

So far, the Otranto excavations provide the only good example of such late kilns in Italy, and few others are known elsewhere. However, well-executed pottery, often painted, characterises not only late antique, but also Early Medieval archaeological contexts, particularly in the major towns in the central and southern parts of the Italian peninsula. The quality of ceramics in Rome, Naples and Benevento, from the 8th c. onwards, was high, whilst in both Rome and Otranto, and perhaps elsewhere (Naples?), lead glazed pottery was also produced around this time (see below). This all rather suggests that the demands of substantial urban populations supported professional ceramic manufacture and that, where Byzantine influence was relatively strong, traditional forms of production were maintained. This, of course, pre-supposes continuity in production technology, including the use of Roman-style kilns, around such centres of Byzantine control or influence. Furthermore, even the forms of ceramics circulating in these Italian cities were closely similar, and find parallels in vases circulating in such distant centres as Gortyn (Crete), Constantinople, and Cherson in the Crimea.[38] It is hard not to see this as evidence for Byzantine connectivity across the Mediterranean, even during the most difficult centuries of the Early Middle Ages.

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[37] Leo Imperiale (2004).

[38] Gortyn: Vitale (2001); Constantinople: Hayes (1992); Chersonesos: Sedikova (1995).

In various other parts of Italy, as in Greece, particularly in rural communities and inland areas, standards of manufacture dropped quite significantly after the 6th c.[39] Open firing or the use of clamp or bonfire kilns may have become the norm for pottery manufacture, though there is understandably little evidence for such practises due to the insubstantial remains likely to be produced. David Whitehouse indeed suggested that "in sparsely populated areas... home production accounted for the majority of pottery made in the South in the seventh and early eighth centuries".[40] It is almost certainly not by chance that much more is known about Roman ceramic ateliers than Early Medieval ones. The decline in the scale of production and the use of simpler technology in ceramic manufacture will have resulted in the survival of less conspicuous remains. In addition, the relatively limited scale of research and publication on the late and post-classical Mediterranean when compared to work on earlier times, is also a further and significant cause of present ignorance. Hence, we are still in need of more systematic analyses of firing conditions and manufacture to chart effective technological changes from area to area.

Continuity

Thus, both hand-made and wheel-turned pottery throughout most of the old Roman world shows a substantial decline in production technology through Late Antiquity and the Early Middle Ages, with more rapid change taking place in the West, than in the East. However, this decline was not universal. Indeed, it is interesting that the greatest measure of continuity in ceramic technology and typology was in the very area where one might argue that the greatest political change took place, the new Islamic Near East. The spread of Islam, particularly after the creation of the Abbasid Empire, hastened contacts between the Mediterranean and the Far East, from which new technologies and styles were soon to appear. But well before the shift of its capital from Damascus to Baghdad in the mid-8th c., the Arabic Ummayad dynasty had guaranteed technological continuity and development from Late Antiquity, particularly in the Levant and in Egypt. It is not surprising that this is the area of the Mediterranean where the circulation of bronze coinage continued unabated well after the 7th c., surely a sign of continued economic complexity and fluid daily exchange.[41]

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[39] Arthur and Patterson (1994).

[40] Whitehouse (1986) 575.

Continuity is perhaps best seen in the manufacture of various ceramic containers or amphorae, vital to the maritime transportation of surplus agricultural products such as wine and oil from the producer to the consumer. This is apparent, for instance, in well-stratified ceramics from Beirut.[42] High-quality production was already maintained by Byzantine ateliers into the 7th c. and, indeed, even beyond in some areas. The economic regime set up in Egypt and the Near East does not appear to have been greatly disrupted by the Arab conquest, so that even pottery production continued along pre-established lines. Doubtless some of this was due to the absorption within Arab society of people whose background was broadly of Roman lineage, thus guaranteeing continuity both in the forms of manufacture as in the use of the vessels. However, more significantly, it suggests little disruption in the surplus production of agrarian products such as oil and wine, and in the organisation of their packaging and transportation for extra-regional, and perhaps even overseas, markets. It is revealing that Christian monasteries such as the one excavated at Um Er-Rasas, were still able to decorate their buildings with mosaics in A.D. 756, long after they had been absorbed into the new Islamic state.[43] Palestinian amphorae of Roman and earlier Levantine tradition continued to be produced at Khirbet el-Mefjar in the 8th c., whilst excavations at the town of Pella show pre-Islamic potting traditions surviving into Abbasid times.[44] Similarly in Egypt, Late Roman amphorae types continue to be produced at least into the 8th c. By the time of the Geniza papyri, however, it would seem that skins were preferred over other transport containers in Fatimid maritime commerce.[45]

Throughout Byzantine territories, amphora standardisation seems to have become more marked from the 7th c., both in terms of capacities (smaller than before and evening out around 30 litres) and forms (often assuming a plain globular shape). It was only by the later 9th or 10th centuries that Byzantine amphorae, like their earlier Roman predecessors, began to assume a variety of shapes.[46] Smaller amphorae, may reflect a decline in carrying capacities because of a decline in the quantities of surplus products to be shipped, but they may also have been adopted following technological difficulties in manufacturing large vessels on the wheel, or in firing them.[47] Whatever the case, Reynolds has pointed out that organic tempering of clays used in amphora manufacture appears to become more frequent by the 8th c., perhaps suggesting difficulties in firing relatively large vessels.[48]

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[41] Ward-Perkins (2005) 115–16.
[42] Reynolds (2003).
[43] Piccirillo (1986).
[44] Walmsley (1988).
[45] Goitien (1967) 334.

Nonetheless, in general terms, ceramic continuity through Roman and well into Byzantine and Arab times appears particularly strong in the manufacture and the forms of certain transport amphorae, as well as being reflected in the types of cooking and storage wares. Instead, other ceramic forms in Arab Egypt and the Levant changed more abruptly, indicating influence from further east. This took the form of changes in form, induced by different cooking and eating habits, changes in decoration, induced by taste and religious ideology, and the diffusion of both lead and alkaline glazing (including gold lustre wares) already by around A.D. 800.[49] The new Islamic glazed wares were eventually to influence the styles and forms of glazed wares being produced in Byzantium and even further to the West, though alkaline glazing remained almost exclusively an Islamic tradition, until it was taken up by Italian potters in the later Middle Ages. If, in areas that fell under Arab control, 'Roman' ceramic transport containers took longer to disappear than 'Roman' fine wares, it may be argued that the former continued to represent an economic necessity, whilst the latter eventually succumbed to new cultural and social dictates.

Ceramic change also occurred through the Arab-controlled Maghreb, though throughout the old provinces along the northern coast of Africa this seems first to have taken the form of technological decline with respect to late antique times, with an increment in the quantity of hand-made pottery circulating. As in much of the rest of the old

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[46] Capacities: McCormick (2001) p. 103, n. 82 and p. 111. Forms: Demestich (2005). 9th–10th c.: Gunsenin (1990).

[47] Large pots produced at Hierapolis in Middle Byzantine times often bear pierced surfaces to help reduce the risk of wastage through thermal stress during firing. Such a problem did not appear to worry the Roman and earlier Byzantine potters at the town.

[48] Reynolds (2003) 732.

[49] Mason and Tite (1994) 34–35.

Roman Empire, pottery from these areas appears to indicate some form of regression with respect to the past, perhaps caused by a decline in their economic base with respect to the richer lands of Egypt and the Near East.

Lead Glazing—A New Technology?

The evermore careless production of pottery in the western Mediterranean in Late Antiquity contrasts with one strikingly positive feature: the appearance, in certain regions, of the use of lead glazing on domestic pottery. The technology of lead glazing had already been used in late Hellenistic and Roman times for decoration of fine table wares (e.g. Asia Minor, central Italy, Gaul), often intended to make ceramics simulate more costly vessels of gold, silver and bronze. It was normally created either as a lead oxide applied directly to a non-calcareous clay body or as a lead oxide and silica frit applied to a calcareous clay body.

The various production centres of lead-glazed ceramics in Pannonia and northern Italy, particularly around the northern Adriatic, may be linked to the supply of the Late Roman army along the Danube *limes* in the 4th and 5th centuries.[50] A clear example of the manufacture of lead-glazed pottery in Late Antiquity is now provided by the publication of an important kiln complex unearthed at Carlino, near the northern Adriatic town of Aquileia.[51] Why, however, this technique should have been favoured by the army has not yet been sufficiently explained. The production of such pottery appears largely to have ceased in Pannonia following the invasion by the Lombards, though it continued on a lesser scale in Italy even after the invasion of the peninsula in A.D. 568. It was presumably transmission or collaboration between Lombard and late antique Italian or Pannonian potters that led to the manufacture of 'Lombard' glazed and wheel-turned pottery found at sites such as Brescia. By the first half of the 8th c., the use of lead-glazed pottery was spreading in and around both Constantinople and Rome, and later appeared in Carolingian Europe. The principal unanswered question is what sort of connection was there between Late Roman lead-glazed wares and those of Middle Byzantine date? Various scholars have highlighted the chronological problems in bridging the gap, particularly for the 6th and 7th centuries.

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[50] Arthur and Williams (1981).

[51] Magrini and Sbarra (2005).

However, it may be noted that small quantities of imported glazed *mortaria* appear at Constantinople and Corinth in the 6th and 7th centuries. At the same time, other forms also appear sporadically on sites in Asia Minor and the Aegean (e.g. at the town of *Anemurium*; on the Yassi Ada wreck, near Bodrum). John Hayes sees it unlikely that the Byzantine glazed *mortaria* are linked to the late antique glazed *mortaria* of central Europe, observing that apparently "a century or more separates the two series".[52] He sees the latter as not surviving the Barbarian invasions of the early 5th c. However, part of the late antique group are surely the lead-glazed wares found at Ravenna and Classe that go into the 6th c., which may be linked to sporadic outliers of such pottery found in central and southern Italy (Rome, Naples and Centoporte, near Otranto—late 5/early 6). In Constantinople, Glazed White Ware I appears by the first half of the 7th c. Can we really believe in a pure coincidence of lead-glazed *mortaria* appearing independently, 100 years apart? My own belief is that technology was transmitted to Constantinople either down the Danube or through maritime contacts with Ravenna in this period. During the 7th c., glazed pottery production ceases in Northern Italy, though it appears to be picked up in eastern Sicily. Products found at Catania and Syracuse, with their applied petals, recall both earlier wares from the Ravenna/Classe area, and later wares from Constantinople and Rome/Naples, suggesting technology transmission through Byzantine networks.[53]

Lead-glazed pottery from sites in north-eastern Spain seem, instead, to have little to do with the productions attested in Italy and further east, though may be indirectly linked, as might be suggested by finds from southern France. Bowls, casseroles with lug handles, and other vessel forms, have been identified at Tarragona, Barcelona and even in 7th c. levels at Cartagena.[54]

The substantial demand for table wares in Constantinople, where the population probably never dropped below around 100,000, guaranteed technological continuity and development of the ceramic workshops supplying the eastern capital.[55] By the 8th c., finely potted dishes were being produced with green and brown glazes over a white ceramic body, sometimes decorated with incised motifs and imitating contemporary metalware.[56] By the end of the 8th c., very similar lead glazed chafing dishes were being manufactured in Italy and in Asia Minor (Constantinople, Hierapolis and almost certainly elsewhere).

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[52] Hayes (1992) 10 and 13.

[53] Paroli (2003) 591; Paroli *et al.*, (2003); see also Dark (2001) 60–61.

[54] NE Spain: Bonifay and Vallauri (2003). S. France: Macias I Sole (1998) 812.

New Ceramic Forms

Technological changes of the period are generally negative: gradually less care is taken in ceramic production, first in western Mediterranean Europe from late antique times (excluding N. Africa), and then in Greece/Asia Minor and North Africa from the 7th c. Yet quite apart from this, some ceramic forms change or become more frequent in archaeological contexts to the detriment of others.

For instance, portable bread-ovens or *clibani*, already known in pre-Roman times, appear to become more frequent through the 5th and 6th centuries in Italy and parts of the Balkans. They abound in later centuries.[57] This form's increasing presence in late antique and Early Medieval urban contexts might be an indication of the ruralisation of the urban habitat, with the disappearance of the public bread ovens or *pistrina* that were so common in Roman times. In the Later Middle Ages, perhaps with the re-appearance of large-scale baking facilities, the form disappears from urban contexts.

In Romania, Moldova, the Ukraine and Bulgaria, flat baking pans appear in the 6th and 7th centuries, that seem to have been used for preparing flat loaves of wheat or millet bread.[58] Such vessels have also been noted in Late Roman and Early Medieval contexts at the town of Luni in Liguria, and their appearance might echo that of the *clibani* in urban contexts.[59]

To take another example, many areas in Roman times were characterised by the presence of flat-based cooking pots, not North Africa though and the Near East. The use of these pots continued in certain Byzantine areas, such as at Constantinople. Generally, however, there appears to have been an increase in the use of round and sagging-base cooking pots in the Early Middle Ages. In areas where flat-based cooking pots disappeared in Late Antiquity and the Early Middle Ages, they appeared again later. It is perhaps likely that the increase in sagging-based cooking pots is related to changes in styles of cooking and their relative supports. Pots with sagging bases are better adapted to placing within hot embers or above a fire, like cauldrons or on a brazier, ensuring a more equal distribution of heat from a flame, whilst flat based vessels are better suited to being placed on a flat surface, perhaps within an oven. So, if on the one hand the change may be related to the cooking of new foods, on the other it might reflect the decrease in quantity of cooking on flat surfaces. Flat cooking surfaces pre-suppose more formal architecture and the stability of cooking areas (e.g. fixed built ovens as opposed to temporary open hearths). Open hearths as opposed to built ovens are also better suited to communal gathering around a fire (thus also providing heat and light sources). Ovens, instead, are more characteristic of domestic architecture that includes functionally-specific cooking areas or kitchens, separate from dining areas, as were common in Roman middle to upper-class housing. The available archaeological evidence so far shows a total lack of ovens even in fairly high-class Byzantine houses.[60] The available evidence may well suggest that the change in cooking pot types not only reflects a change in cooking techniques, but also in social organisation, with more flexibility and adaptation, partly responding to a premium on domestic space. Perhaps we should see the introduction of portable braziers in Spain by the Arabs, and of chafing-dishes in Byzantine territories, in a similar light.

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[55] Mango (1980) 62, considers more than 300,000 people in 5th c. A.D. Constantinople realistic.

[56] Hayes (1992) 15–17.

[57] E.g. Lavazza and Vitali (1994) 43–47, for Lombardy and Friuli; Cubberley, Lloyd and Roberts, (1988) in general.

[58] Curta (2001) 295–96.

[59] Lavazza and Vitali (1994) 48.

Whatever the case, one lead-glazed ceramic form—the so-called chafing-dish—stands out. It appears for the first time during the course of the 8th c.[61] Some scholars see this new form as having been devised for the preparation of warm fish sauces, though other explanations have been put forward, such as use in the preparation of mulled wine. A similar recipient, in modern Turkey, known as a *mangal*, is used for meats, particularly mutton, whilst another example, in a 17th c. painting in the Museum of Lisbon, Portugal, is being used to roast chestnuts. Perhaps this dish was not specific to a particular food, but generally employed for warming meals in a society where kitchens were not generally available. Whatever the vessel's precise function, it appears to be a rather culturally-specific item. Numerous examples were made and have been found in Rome, and are distributed in various parts of southern Italy and Sicily, particularly in port-towns (Naples, Otranto, etc.), with an outlier as far west as Mallorca.[62] They have also been found in Greece and Albania, in the Aegean and eastern Mediterranean islands, on mainland Asia Minor, around the Black Sea and, in very significant quantities, in Constantinople, where they were also made. Clearly many production sites existed throughout Byzantium. The distribution of known examples thus appears to draw up a pattern that rather closely fits the map of Byzantine territory and its satellites in the 8th and 9th centuries. This is particularly interesting in underlining the diffusion of socio-cultural models that unified even the most far-flung areas of the empire, helping to characterise them as part of a Byzantine *koiné*.

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[60] Sigalos (2004) 58–59.

[61] Paroli, *et al.* (2003); Vroom (2005) 72–73. The form actually recalls some ceramic 'braziers' known since the Bronze Age.

Excavations at both Hierapolis and Troy in Turkey also suggest the appearance of another new ceramic form, the alembic. Similar vessels were recently used in the distillation of alcohol for the production of the Turkish *raki*.[63] The distillation of alcohol is attested amongst the Persians by the 8th c. and a couple of glass alembics, found in the excavations by Margaret O'Hea of an Abbasid complex at Pella in Jordan, have been dated to the 9th c. By the late 10th c., the Arab doctor Abulcasis described the use of distilled alcohol as a solvent for drugs in Spain. The ceramic alembics from Hierapolis, decorated with finger-impressed cordons, and found mainly in the excavation of the large baths in the centre of the town, are of local manufacture and may be dated to the 10th or 11th c., prior to the arrival of Seldjuk Turks in western Asia Minor.

The 8th c. is known as a period of increasing Arab influence in the Byzantine world. Indeed, the iconoclast controversy began in A.D. 726, as a result of oriental influence in Christian cult, though cultural admixture ran far more deeply and may even have influenced culinary traditions. Perhaps both the introduction of the chafing-dish and the alembic should be seen in the context of increasing Arab influence on the Byzantine world. Thus, it would be interesting to know when pit-hearth cooking, also attested at Hierapolis, first began in the eastern Mediterranean. This form of cooking appears to have come from the East, perhaps from nomadic Arab societies, but the earliest examples that I am aware of in Asia Minor do not, at present, seem to predate the arrival of the Seldjuk Turks in the 11th c. But all of this leads to a new story.

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[62] Rosselló (1982).

[63] For Troy see Hayes (1995); Hierapolis: Arthur (2005) and Cottica (in press), who prefers to identify the vessel as a wine-thief. I should like to thank Ilhan Unlüsay (Antalya Museum) for having discussed the use of the 'imbik with me.

A Summary of Trends

At the risk of simplification, if we attempt to look at ceramics with a sweeping Mediterranean and European-wide view, between Late Antiquity and the Middle Ages, what general trends can be seen? At the risk of gross simplification, I think that they can be summarised as follows:

1. A trajectory of decline is witnessed in most areas of the old Roman Empire, from north to south, and from east to west, with the principal exclusion of territories that were to depend on Damascus following the Arab conquest.
2. The disappearance of large ceramic factories that depended on inter-regional trade to reach large markets.
3. A decrease in the variety of ceramic types.
4. The gradual addition of some new forms that may indicate a ruralisation of the old Roman urban culture.
5. A greater quantity of round and sagging-base cooking pots (but not in North Africa, where they were already current throughout Imperial times).
6. A reduction in the size and simplification in shape of transport amphorae, and also in their quantity and distribution.
7. A greater use of lead glaze on pottery in some areas, and an almost total disappearance of totally slipped pottery that characterised much of Roman table ware production.
8. Manufacture that, at times, was rather coarse or slovenly. In the second half of the 7th c. there was even an impoverishment in the techniques of production of African Red Slip Ware (Bonifay).

9. Many of these changes in ceramics must reflect changes in cooking techniques.

Explanations

It is quite remarkable that more or less contemporaneous changes took place sweepingly across almost the whole of western Europe and much of the Mediterranean world, though from north to south and west to east. Obviously, the various areas throughout the old Roman Empire differed, as they varied in terms of cultural make-up, and in terms of high and low population densities. But in most areas of the Mediterranean, there was no substantial change in the basic technology of ceramic production, but rather an aggregate move towards less professional workmanship and the transformation of vessel types. Despite a certain amount of cross-cultural influence, we are witnessing the results of what appears to have been a collective and presumably subconscious transformation dictated by changing social, cultural, economic and environmental factors, some general, pertaining to the entire ancient world, and some individual, region to region. The arrival of nomadic or semi-nomadic peoples in various parts of Europe and the Mediterranean from Late Antiquity, for instance, may have led to a greater use of hand-made pottery which did not have to rely on particularly sophisticated equipment or infrastructures for its manufacture. The differing individual responses across the ancient world are, perhaps, in some way natural responses to changing conditions. The predominant trend of quality decline, however, may be linked to various factors:

- the generalised need to save on time and costs.
- a substantial decrease in the demand for high-quality (and more costly) products, with greater emphasis on far more basic priorities in daily life.
- less commercial contact through Europe and the Mediterranean, though it is clear that the scale of exchange has been underestimated in the past.
- a move from full-time or professional potters to a greater proportion of part-time potters.
- aesthetic values succumbing to purely functional or practical ones, within the more general context of changing values.

- the need for lesser variety in ceramic types concomitant with the decrease in food resources and a simplification of food dishes and eating rituals. Too little is known about culinary habits, traditions and transformations. Indeed, the appearance of some new foods and recipes, or an increase in 'rural' recipes, was perhaps largely caused by a diminution of ingredients. Are we perhaps seeing the beginning of the healthy Mediterranean diet that survived into the 20th c.?

We cannot properly study pottery if we do not study what it was used for. It is for this reason that I feel that the major way forward is to put far more emphasis on the analysis of food and eating trends, with their social and economic implications, as Joanita Vroom has so brilliantly attempted for Boeotia.[64]

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[64] Vroom (2003).

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METAL PRODUCTION IN LATE ANTIQUITY: FROM CONTINUITY OF KNOWLEDGE TO CHANGES IN CONSUMPTION

Enrico Giannichedda

Abstract

The study of metal production in Late Antiquity falls between the Early Roman period and the Early Middle Ages—both of which left a more lasting impression. Late Antiquity marks an ambiguous boundary, or rather a period of transition in which significant continuity of knowledge of ancient techniques can be found, although sometimes translated into new forms, as a result of: a crisis in extraction activities of the central government; of contacts between peoples who brought with them different traditional techniques; and of changes in use, whether utilitarian or not. To examine these phenomena, three methods can be applied: firstly, one can differentiate products through their technical details; secondly, one can quantify production, and thus the metal that was actually available to the different social groups; thirdly, one can undertake archaeometallurgical research on sites of particular interest.

Introduction

Roman material culture reached a remarkable technological level, notably in terms of the manufacture of metal objects, which were widely distributed during the first centuries of the Empire. This simple observation once led some historians[1] to ask why, in Late Antiquity, the Roman World did not produce an industrial revolution. This debate was obviously connected with a view of Late Antiquity and the Early Middle Ages as a period in which much knowledge was lost, including proper technical knowledge. However, this discussion can be sidestepped if one

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[1] Gibbon (1776); Rostovzeff (1957) 535 asks, from a Romanocentric view, "why does modern society always have to build upon the ruins of Antiquity, instead of being its direct continuation?".

L. Lavan, E. Zanini, and A. Sarantis (edd.) *Technology in Transition A.D. 300–650*
(Late Antique Archaeology 4 – 2006) (Leiden 2007), pp. 187–209

considers the factors that made it difficult for something even vaguely resembling an industrial revolution to occur in the Roman world.[2]

Firstly, the Romans thought of their world, as being the best of all possible worlds: they did not reason using the modern logic of 'progress', but, on the contrary, "they thought they had reached the end, but they hadn't even started".[3] Secondly, it was typical for the Roman world, in terms of social behaviour, to think of a vicious circle of wealth accumulation and loss, which was characterised by income distributed according to social status, and the absence of an economic logic driven by investment in productive activities. This was, furthermore, a society that in essence founded its wealth on the spoils of wars of conquest. A society which indulged in enormous waste—well illustrated by the luxury of private residences and public places—and which excluded the sphere of production and the trading economy from the ensemble of values that they perceived as positive. Thirdly, slave-organisation was present in every branch of production, where larger profitability could easily be reached by increasing the work force at low cost, instead of investing in mechanisation or improved power sources.

Together these three factors suggest that the typically medieval experience of a combination of technique and science was not achieved. This combination, in later centuries, provided the basis for subsequent developments of a world that can be straightforwardly called pre-industrial, and was based on a completely new mentality and organisation that had been created with difficulty in the Middle Ages.[4] It was in the Middle Ages (13th–15th c.), in fact, that mechanisation occurred—which led to the study of the physical powers at work during processes of production—and the intensification of trade, supported by an increase in demand for consumer goods. Unquestionable and enormous changes occurred from A.D. 1000 and which differentiate ancient from medieval metallurgy, especially in terms of scale.

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[2] Schiavone (1996).

[3] Schiavone (1996) 163.

[4] See for this topic: Giannichedda (forthcoming a). Rather dated, but still essential because of the extensive work with which they approach the technical problems are Gille (1985) and Gimpel (1988). The complexity of the relationship between technique and society in Roman society is very noticeable in, for example, Ciarallo and De Carolis (1999); González Tascon (2002).

Conversely, one cannot argue that technological knowledge was simply forgotten during Late Antiquity and the Early Middle Ages. During the last few decades, archaeological research has revealed that the transition did not really involve a loss of artisanal ability: this did happen in some regions, but it was not universal. Rather, there was a reorganisation of manufacturing to produce new shapes. This was a consequence of, amongst other things, a crisis in the extraction activities of the central government, of contacts between peoples with specific traditional techniques, and from changes in use, either in products for everyday use, or in luxury goods. At the same time, Late Antiquity constitutes an exceptional case for studies of technology: it is the only period in European history for which it is possible to hypothesise the existence of an enormous but unrealised potential for technological innovation. This raises a whole series of related problems: that of the relationship between technical knowledge and society; of the real causes of innovations which were possible but never occurred; and of the role that practical use played in conditioning production. Furthermore, Late Antiquity is perhaps the only case—or the most complex case– in which the prolonged contact between different peoples, after several centuries of dominant Roman culture, witnesses a reversal of roles. The once-dominated barbarians became the dominators, and this affected the circulation of prestige technologies, in such areas as individual ornaments and weapons.

In order to understand the metallurgy of the period, it is necessary to differentiate between a great variety of socio-economic backgrounds in the Mediterranean and Europe between the 4th and 7th c. The period is marked by the temporary disintegration of urban society in a large part of the West, although in the East, where towns survived for longer, there was a lasting development of centres of excellence, destined to long fortune and to act as intermediaries with the Asian world—culturally and technically, as well as economically. It is clear that these regional historical frameworks were not simply passive backgrounds against which craftsmen in metallurgy can be set. Rather they produced the decisive causes of various processes: the cessation of some craft industries, local crises, or the displacement of workmen. However, to go deep into themes as complex as these is obviously beyond the scope of this article. Thus this text is limited mainly to an examination of metallurgy in Italy and adjacent regions. It should not be read as a definitive study, but rather a preliminary discussion for more detailed research, presenting some methodological perspectives which appear to be worthwhile developing further.[5]

In Italy, the study of late antique metallurgy is comparatively neglected. Metal production of the 5th and the 6th centuries is situated between the studies of the Early Roman and the Lombard periods, which both have a high degree of prominence, on account of the nature of the evidence and the history of research to date. In this intermediate position, the metallurgy of Late Antiquity is reduced to being a boundary-marker, though certainly not a clear one; today it seems to be characterised by substantial continuity of knowledge. Such continuity often still waits to be proven, but logically it cannot be doubted. Unfortunately, each chronological division introduces and emphasises elements of discontinuity in the historical process, to the detriment of elements of continuity, which are just as significant: for example, the "crisis of the Empire", in reality, did not occur at the same time or in the same manner in all regions, the difference between the East and the West being especially marked. Yet our understanding of continuity and transformation of metal technology in Late Antiquity has to be placed in the context of a longer timeframe: the techniques and metallurgical production of Late Antiquity and the Early Medieval period cannot be characterised if they are not connected to techniques in adjacent historical periods: the Early Roman period and the Middle Ages. Thus we can talk of the study of metallurgy in Late Antiquity, even though it is unhelpful to talk of 'late antique metallurgy' as a recognisable entity.

The evidence for metal technology in Late Antiquity is complex and its problems cannot be summarised in the space of this article. Nevertheless, some essential remarks can be made. Archaeological research depends on the nature of evidence preserved, which in its turn is the result of (specific) choices, often of a cultural or non-technological nature. These might be different burials customs (with or without grave-goods), the perception of an imminent danger, which drove some people, at certain moments and in specific areas, to deposit buried treasures, which contained metallic objects.[6] Textual research is strongly influenced by the fact that the literary and epigraphic evidence primarily concentrates on three areas. Firstly, texts reveal the important role played by late antique guilds—especially goldsmiths, silversmiths and coin minters—and the existence of forms of specific craftsmanship, which led to the distinction of more than 130 different occupations in the Early Roman period.[7] Secondly, we hear of the existence of large factories under government control, often military, either near the *limes* or within large urban centres; at the moment, none of these factories has been archaeologically investigated and it is not always clear which products should be attributed to their activities. Thirdly, the texts reveal the possible role of travelling craftsmen: from the 4th c. onwards, the law excluded at least goldsmiths from the obligation of residence; the mobility of these craftsmen can also be assumed on the basis of the simplicity of tools used by ancient goldsmiths, which were not dissimilar to those of a modern coppersmith.

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[5] Generally on the topic: Davies (1935); Tylecote (1962) and (1976); Healy (1978); Craddock (1995). Among the most recent works, with references to previous works, that discuss metallurgical production in Antiquity see the various formulations of the problems in Giardino (1998); Formigli (1999); Giumlia-Mair and Rubinich (2002); Guillaumet (2003). For the Middle Ages see Francovich (1991) and (1993); Magnusson (1995).

As this remark suggests, apart from archaeological and textual sources, much knowledge of technological conditions can also be derived from analogies with later periods about which we are better informed: sometimes studies of late antique metal objects make it possible to deduce obvious parallels. For example, medieval goldsmiths characterised by tightly controlled technical knowledge, which was only passed on to a few people, usually only within the family. This development of individual skills, which link empirical knowledge to the development of individual abilities, can only occur in restricted spheres, in which a youth completes a training, based on workshop practice, and thus on the knowledge of a small group. This method of knowledge transfer requires a long apprenticeship—in any period—which in the case of metallurgy, involves a craftsman either dealing with processes of metal smelting, or applying finishing touches to valuable objects. The control of knowledge of this technology—obviously linked to the defence of one's own interests—has always ensured that metallurgists were perceived as a separate social group and, also because of this, inclined to move, sometimes over large distances, depending on opportunities to work (which were conditioned by the availability of materials, buyers and of markets).[8] These specific characteristics of metal-workers can actually be seen in Late Antiquity through an analysis of the technical aspects of the craft, connected to the various stages of metallurgical production, from the extraction of the metal to its transformation into a finished product.[9]

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[6] On these topics see especially Gelichi and Giordani (1994); Baldini Lippolis (1999).

[7] Baldini Lippolis (1999); Vidale (1992) 38–39.

Extraction

By nature, extraction activities are undertaken primarily in relation to geological knowledge of a "site": that is to say, technical knowledge of the characteristics of a territory, which cannot be conveyed over a great distance, but which is relatively simple and stable. This continuity, for example, is shown by the use, even still in the Middle Ages, of extraction techniques developed by the Greeks and Etruscans. But one thing that definitely changes in Late Antiquity and Early Middle Ages is the organisation of production, due to the decrease of imperial control over mining activities and to the reduction of long-distance trade. During this period, metals do not seem to have been considered to be 'strategic' goods, which the state ought to control. The reorganisation of production set up a differentiation between areas near extraction centres and those further away, which now became short of raw material. Here we should recall decisions taken by Theoderic, concerning the recovery of gold from graves and the dispatch of an expedition into Illyricum in the search for iron.[10]

Most archaeological data for this period comes from two marginal areas of the empire: the Iberian Peninsula and Central Europe, more specifically Noricum, where the quality of the extracted material made the production of steel much easier. The growth of production in Central Europe, well-attested by various sites with traces of metal smelting, can be linked to the manufacture of weapons but also to problems of supply: here there had never been many cities so it was impossible to recover large quantities of Roman iron from abandoned urban sites. Conversely a massive decrease in both the production and use of iron seems to have occurred in Switzerland, France and Wales. This sudden reduction of production could have been caused by a crisis in demand. But it is also likely that iron was being recovered here from abandoned Roman sites. The low number of late antique finds here could also be the consequence of later recycling, which was perhaps more intense in these areas.[11]

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[8] For much of Europe, a succession of metallurgists of Roman origin played, for over a millennium, an important social and productive role, either in the countryside or in the service of feudal rulers or in large urban centres; Rebuffel (2004).

[9] For an introductory description of production cycles see Hodges (1976); Mannoni and Giannichedda (1996); Giardino (1998); Tizzoni (2004).

[10] Cassiod. *Variae* 3.25–26 (iron in Dalmatia), 4.34 (gold from graves), plus see 9.3 for simple gold mining.

In most regions, the closure of government-owned mines probably led to the dispersal of technical knowledge, followed by a total cessation of production. However, in some places, these activities were carried out on a reduced scale using the same techniques. This can be indicated by the preservation of inherited skills as in the Alpine valleys, where techniques continued unaltered until well after the Early Middle Ages[12] or by elevated social status enjoyed by specialists, indicated by the frequent appearance of miners and metallurgists in prominent positions in 8th c. documents.[13] The mines of Linares in Spain definitely stayed active at all times, as did many other iron-mines, although they contained lower quality ores (for example in the Alps). But with the crisis of the central system, great large-scale excavations ceased; these had combined the use of slaves and hydraulic power (*ruina montium*), whereby great quantities of water were released across open-cast sites.[14] However, the supply of raw materials was connected not only to extraction, but also to the recovery of slag and to the recycling of metal from broken or abandoned, but finished, products. In Spain, for example, the recovery of metal from slag was already regulated during the reign of Hadrian.[15]

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[11] For the different aspects of the problem see Pleiner (2000).

[12] Cuomo di Caprio and Simoni (1989); Cucini Tizzoni and Tizzoni (1999).

[13] For the social characterisation of metallurgists and comparison with further sources see La Salvia (1998), Giostra (2000).

[14] Gold washing (*aurifodinae*) probably continued in the Piedmontese rivers, even if only on a smaller scale.

[15] González Tascon (2002) with earlier bibliography.

SMITHING

Extracted metals comprise three major families: i) precious metals (especially gold and silver), ii) bronze alloys (copper, zinc and tin) and iii) ferrous metals. Mercury and lead were much less important. In Antiquity, lead was mostly used in cities, or in high-value contexts, either for pipes or when, together with tin, it made up pewter. Nevertheless, lead was at least being re-used in Late Antiquity: for example at Castelvecchio di Peveragno (in Piedmont), lead ingots were found in a settlement of the 5th–6th c., characterised by metallurgical activity; this led to the interpretation of the site as something more than a simple rural smithy.[16]

Precious Metals

The smithing of precious metals—which are, more than others, functionally useless, but rather support artistic representation—certainly did not go through any crisis. This is proven by the history of silver plates: already of a very high standard in the Augustan period, they include true masterpieces produced between the 3rd and 6th centuries, which combined the use of various techniques: repoussé, the use of burin and chisel, and the development of complex processes like gilding and niello (an amalgam of iron with copper and lead, poured into the grooves of the surface that was to be decorated). The goldsmith's craft proper, also saw the continuation of ancient techniques—including filigree and granulation—which were used in objects to satisfy a new taste, featuring colour-effects with precious stones, colour contrasts, and drawn-thread work (*opus interassile*).[17]

Our knowledge of the organisation of craftsmen themselves is limited. It is not now credible to maintain a clear distinction between the Late Roman-Byzantine goldsmith and his barbarian counterpart: in fact, the more precious and the less bulky the material was, the more transportable were it and its artisans; the iconography, for example on the silver plates, shows the coexistence of pagan and Christian depictions, whilst technical analysis of Early Medieval dress ornament shows a high level of interchangeability of finishing processes between 'Barbarian' and Roman metalwork.

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[16] Micheletto (1995) 139–48.

[17] For the technical characterisation of this process see Giardino (1998); for historical considerations see Baldini Lippolis (1999), *Milano capitale* (1990) both with previous bibliography.

We can suppose that works of great prestige were undertaken by only a few craftsmen, who were connected to the ruling classes. In other periods, we know these men could relocate, either in pursuit of aristocratic patrons, or between different urban centres. Craftsmen were able to move over long distances, with their own tools, to areas that were at any given time richest in raw material, or to look for employment. However, the concentration of economic resources in Late Antiquity in the hands of a restricted social elite, residing in a few centres, makes it less likely that goldsmiths in this period were itinerant, and more plausible that they were sedentary, adapted to local circumstances. With a strong social role and specialised knowledge, a goldsmith could easily move on and take it with him, if he had to. But it is, at present, difficult to provide an answer to this question. One way to study artisan mobility would be to try to identify if regional or very localised workshops existed. Scholars still need to work harder to identify such workshops, according to techniques used, the typology of products and their chronology. Perhaps some future insights into the profession will come from considering coins. The tooling of precious metals cannot be separated from questions concerning minting (including the visible hoarding of money in the form of medallions) or, alternatively, from the fine-smithing of bronze materials, used as dress accessories.[18]

Copper Alloys

The manufacture of objects in copper alloys is perhaps the most interesting commercial sector of metallurgy, because it connects very specialised uses (including use for weapons) to others that are less or not at all specialised. These include, on the one hand, clothing accessories and crockery, on the other, artistic handicrafts: from furniture, to urban fittings, to the use of copper alloys in precious objects, and in association with other materials. In addition, smithing techniques for copper alloys combine processes that are typical for iron and steel dressing (such as hammering) with those typical for precious metals, either hot or cold. Given the wide spread of bronze products in Antiquity, this was an area of artisanal specialisation, which could be considered to be of intermediate rank between ubiquitous ironsmiths and rare goldsmiths. The nature of the material, which is preserved in large quantities, and in a better condition than iron objects, makes it possible to make more accurate technical and typological observations.

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[18] Particularly for silver: Leader-Newby (2004).

An important hypothesis, which unfortunately lacks secure data, is the return in Late Antiquity to the re-melting of older materials. Although such recycling is present in all periods, it was perhaps more systematically executed at this time, and perhaps even made use of large amounts of low-value bronze coins. The extent and the nature of recycling, together with the conservation within families of objects over a long period (both 'heirlooms' and more practical objects), should not be assumed but needs to be assessed from site to site: it might manifest itself in very different forms, for example, in urban centres and in the countryside. Evidence for organised recycling, on different levels, includes the robbing of bronze cramps from ancient monuments and the hoarding of bronze laminas that were broken and bent to reduce their size for melting. Evidence for the long-term conservation of bronze objects by families comes from so-called 'domestic' hoards, such as those recovered near Modena, which include examples of diverse date, which must have been treasured over many generations.[19]

Not much can be said about manufacturing installations for copper alloys, either for smelting from raw material, or for smithing of finished metal. Nevertheless, we have a few clues. The evidence from the Crypta Balbi in Rome, relating to a workshop active in the 7th c., shows that, with very little raw material, a great many objects could be produced, different in both aspect and function.[20] Moulds and models found on site reveal choices of standardisation in production, carried out in a large factory, where specialisation can be detected through eclecticism visible in the finishing touches of anything associated with personal ornament: valuable weapons, horse harnesses, small items of furniture and metal cutlery (knives and forks). The discovery of production waste relating to these items, in a Roman context, led to the rejection of a simplistic dichotomy between Italo-Byzantine and Lombard metalwork, as both styles were present. This naturally led scholars to assume the persistence of a system of exchange, over great distances and between different ethnic groups, which appears very rational for high value goods such as metal. It appears to be proven in the case of other materials, such as steatite crockery. This product, from the Alpine valleys, continued to be distributed in regions under Byzantine control, even after the Lombard invasions of northern Italy. It reached the South, indicating the viability of trade routes that passed partly by river and sea.[21] Indeed, the finds from the Crypta Balbi really illustrate, even at the end of the 7th c., not just the continuing importance of large urban factories, but the marketing of products over long distances, either towards the East Mediterranean, or much more probably, towards the Lombard centres of central and northern Italy.[22] For this viewpoint, some traditional definitions need to be reconsidered, such as 'Coptic' and the 'Lombard' plates: the latter, for example, are definitely Lombard from the context of discovery, but are significantly less 'Lombard' in terms of their production and their derivation from classical forms.[23]

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[19] Gelichi and Giordani (1994).

[20] Ricci (2001) and the other contributions by the same author, in the same volume.

In the sphere of clothing accessories, there was neither a crisis in the techniques used, nor an introduction of substantial innovations. Continuity was the rule. New types of production seems to relate to changes in taste: for example, esteem for military status or gender differentiation resulted in men making different aesthetic choices from women and vice-versa. Differentiation on the basis of ethnicity or production technology seems less significant. Hence, in the course of the centuries, the shapes of *fibulae* change or techniques which were known earlier but rarely used became widely diffused, especially damascening, but no disruption of a technical nature took place. Continuity of technical processes can also be noticed in cutlery, as is shown in the working techniques of laminas, or the use of rivets or *appliques*, obtained through fusion. Moreover, in many cases, the continued use and restoration of products that had been made two or three centuries earlier can be certified in the 5th c.

Survival and continuity in the technology of large bronze castings can be assumed at the highest level of technical complexity, since the late antique period falls between an earlier period that was characterised by large bronze statues and a later time that was marked by the production of bells, which, evidently, cannot have appeared out of thin air.[24] In addition, bells were manufactured in the Roman tradition (*tintinnabula*) and are attested for Christian liturgical use as early as the 6th c., even if the oldest casting pits with archaeological evidence for a copper alloy so far are only known from the Carolingian Age. It is possible that relevant skills survived in this period through the restoration of bronze works of art dating from Antiquity. However, a single literary source for Italy suggests that bells were not immediately produced there: a letter dating to the middle of the 6th c., in which the gift of a bell is mentioned, made by Ferrandus, deacon at Carthage, to Eugippius, abbot of the monastery at Castellum Lucullanum near Naples.[25] This circumstantial note constitutes an important and direct testimony to the existence of exchange over long distances, but also probably provides a reflection of the crisis affecting some regions in Italy which traditionally are thought to have been centres of bronze-working. Because this anecdote concerns Naples, it seems likely that this crisis even affected Campania, from which the Latin name for a crafted bell is derived.[26]

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[21] Lusuardi Siena and Sannazzaro (1994) 157–88.

[22] Ricci (1997) 268–70.

[23] For an example of a technological study see Giannichedda (1993).

However in the West Mediterranean as a whole, substantial technical continuity in bronze casting during Late Antiquity seems to be proven: in very different contexts the same technical abilities survived, altered though essentially the same in nature, such as casting in pits and lost-wax casting. Although some new phases were added to the cycle, these methods represent a distinct tradition with an ancient origin. Indeed, a treatise on bell-casting by the monk Theophilus, in the 11th c., seems to draw on a much older work, whilst the excavations of casting pits for bells have demonstrated that Early Medieval bronze-casting has classical roots.[27] The technical knowledge associated with great bronzes seems to never have ceased being transmitted. If a medieval 'reinvention' ever occurred, based on the study of surviving ancient products still in use or on suggestions coming from outside Europe, then changes were confined to minor details of the production cycle.

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[24] For the classical bronze-working see Formigli (1999); while for the Early Medieval production of bells see Lusuardi Siena and Neri (2003) and (2004); Giannichedda (forthcoming b) who consider the technical continuity and opportunistic solutions, necessary to manufacture different objects. On Theophilus: Caffaro (2000).

[25] *Archiv fur lateinische Lexicographie und Grammatik* (1900) xi 537–50; I owe this important information to the courtesy of Caroline J. Goodson, whom I thank.

[26] For the situation in the area of Pompeii and hypothesised local production see examples in Ciarallo and De Carolis (1999).

[27] Giannichedda and Ferrari (2001), Lusuardi Siena and Neri (2003), Neri (2004) and (2006), Giannichedda (forthcoming b).

Iron

The traditional technical processes for the smelting of metal do not seem to change during Late Antiquity. We know most about iron minerals, which were worked in simple facilities, either in the open or indoors. These structures were meant to be demolished after use in order to obtain the metal bloom and then rebuilt many times over. Technically, they were not very different from the Early Medieval 'bassofuoco' smelting furnace (the bloomery furnace, using the direct method).[28] But in central and northern Europe, sometimes far beyond the imperial *limes*, a different type of furnace was used, which was more permanent, and allowed slag to be drained away. Sites with hundreds of smelting structures are known, that were used for many generations.[29]

It remains very complicated to date this type of evidence. Thus it is hard to identify when the transition from open furnaces to built furnaces occurred. The former lack almost any structures, except sometimes a little low wall, like those exhibited by Catalan 'bassofuochi'. The latter were filled from above and in some cases possessed a small ditch for the clearing of slag—a slag pit furnace.[30] The latter definitely existed in territories that were not occupied by the Romans, but their adoption within the former Roman empire was not necessarily the result of a clear positive technological choice. From a technical point of view the built furnaces were not indispensable, because iron production remained erratic and small-scale. In fact, in known cases, there is rather an endless number of intermediate solutions, rather than a clear distinction between two types. These variations perhaps reflect variations in the raw materials used, or more or less daring attempts to reduce the subsequent workload by eliminating the slag from the bloom.[31]

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[28] For an introduction and description of the differences between direct and indirect methods see Mannoni and Giannichedda (1996): even more technical and in-depth is Tizzoni (2004). In general, on the topics considered here see Magnusson (1995); Cuomo Di Caprio and Simoni (1989); La Salvia (1998).

[29] Pleiner (2000).

[30] Cuomo Di Caprio and Simoni (1989); Calegari (1981).

This change, even if it is generalised, cannot be seen as some sort of evolutionary process, because furnaces survived that had no evacuation system for slag, even in the post-medieval period. Furthermore, in any 'transition', from one system to another, neither technical knowledge, nor the quantities produced, changed. The blooms, and therefore the transformed ferrous load that was ready for smithing, continued to be quite limited in weight, in the order of 3–4 kilograms per working cycle, which is between 1/20 and 1/50 of the output of the Catalan furnaces of the Late Middle Ages.[32]

The recent identification of the production of cast iron in 5th–6th c. contexts in Val Gabbia, in northern Lombardy, is extremely important; this followed very detailed research, which included reconnaissance, excavations and archaeometallurgical research on finds.[33] The latter revealed the presence of metallic agglomerate with a carbon content of 1.7–4.3%, which was the result of a smithing process at temperatures of over 1500 degrees Celsius. These agglomerates suggest that the adoption of an indirect smelting process was used (within a first phase the production of cast iron). Following the—perhaps accidental—production of cast iron, the opportunity for systematically obtaining this product through suitable processes of refining was seized, crossing the limit—nevertheless very weak—that separated the ancient smelting process (direct) from that which is usually thought to be 'modern' (indirect). So far this has been recorded at sites at a high altitude, near mines of small size. The fact that this shift can be verified in such small places—the total production can be calculated at ca. 2000 kg of iron[34]—makes it possible that numerous small structures for smelting existed elsewhere, spread over the territory, which still escape detection in the field, here as elsewhere.[35] The existence of non-accidental production of cast iron and of its smithing is also possible for other sites, especially in central Europe, but it risks being missed if its archaeometallurgic indicators are not recognised.

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[31] Fluzin (1999).

[32] Cucini Tizzoni and Tizzoni (1999).

[33] Fluzin (1999); Cucini Tizzoni (1999a).

[34] It is, however, necessary to keep the intrinsic value of iron in this period in mind, as testified by the transport of a few tens of kilograms of iron over relatively large distances: Cucini Tizzoni and Tizzoni (1999).

[35] For the late antique site of Ponte di Val Gabbia III, with evidence of smelting and forging near a half-buried hut see Cucini Tizzoni (1999a) 93–140; for the site

In fact, direct smelting is certainly the typical ancient and Early Medieval method to attain iron. But both methods have advantages and disadvantages. The indirect method, for convenience, actually requires structures that are more demanding and costly (a blast furnace and hydraulic bellows) in order to obtain higher temperatures. Consequently, it needs further structures, to heat the cast iron to a fluid state with currents of air, to oxidise and to eliminate most of the carbon, in order to produce malleable iron. The consumption of fuel is therefore higher, but a continuity of the cycle can be allowed, thanks to continuous casting and thus, a higher degree of productivity is reached. This method only becomes profitable when such high productivity is commercially necessary, as with the growth of the iron and steel market in the Late and Post-Medieval period. Perhaps because of this, the diffusion of this method remained limited for centuries, with active installations from the 11th c. in only a few regions. Subsequently, it also co-existed with regions where the direct method was used until the modern period (as in Liguria and some other Mediterranean regions).[36]

Once smelting had been undertaken, the subsequent working of iron comprised, as with other metals, cold and hot working. These methods included hammering, first carried out to eliminate the remaining slag, and then to shape the material (by smoothing, curving, folding, narrowing, twisting) and also other procedures, such as welding and mounting, to join individual pieces, along with burnishing and acieration, which, through sequences of tempering, aims to modify the characteristics of the metal. These important phases of working generally require special tools, like tongs, moulds, punches, chisels and anvils, but these do not leave traces that can be distinguished during the excavation of a workshop. Their existence is almost always only attested by studying the finished products, through simple macroscopic observations. The tools, whose only purpose by nature is to function, generally do not change in their essential design: often modern, pre-industrial objects

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Ponte di Val Gabbia I e II, with two installations for smelting dated between the 6th and 9th c., see Cucini Tizzoni (1999b) 141–82.

[36] Calegari (1981).

can be compared either with blacksmiths' tools from excavated ancient sites, or with the tools that are depicted in monumental sculpture or in epigraphic decoration.[37]

Ancient writers, from Vegetius to Ammianus Marcellinus and Procopius,[38] mention on various occasions the excellence of the weapons of the Goths and the Alamanni. This has been confirmed by recent metallographic analyses.[39] Moreover, archaeological research has also pointed out how in Late Antiquity a substantial homogeneity was reached in the armour used by opposing armies, with the adoption of Roman elements by the Germanic side and the production in Italy of the Lombard *scramasax*, and also of other weapons of 'barbarian' origin, including the *fransisca* (which could also be used as a tool), or bearded axes, of which over 30 examples are known from Italy.[40] The production of swords with damascened parts required great technical ability. From the 1st c. A.D., damascened metal was known to have different qualities of hardness (on the blade) and of elasticity (in the core), due to the close joining and torsion of parts with a different carbon content. But in the migration period we see the development of a new 'Celtic' tradition, with the simple joining of two different bars in a single blade: this may have developed due to import stimuli, coming either from the western damascening (known among the Germani through the import of Roman weapons and contacts with the legions), or from peoples in the North and the East, perhaps even through the Slavs.

The production of agricultural and artisanal tools is difficult to study. The scarcity of well-preserved objects compels us to use indirect considerations, based on the conservation of iron by users as an indispensable material. Either objects had a long period of use or they were continuously recycled. However, slag, revealing the activities of smiths, can be detected in almost all rural settlements that have been researched in sufficient detail: it represents an indirect but significant clue to the importance and diffusion of iron tools.[41] Thus, the existence of village smiths, with their own traditional knowledge, cannot be excluded, though, in many cases, it can be argued that their activities were only carried out on a temporal basis and were, above all, dedicated to the working of recycled material.

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[37] For an example, see the objects in Micheletto (1995), Cucini Tizzoni and Tizzoni (1999) and general considerations on tools in Mannoni and Giannichedda (1996).

[38] Ammiano Marcellino, *Historiae* (ed. A. Resta Barile (Bologna 1976) 174); Procopius Caesariensis, *De Bello Gothico* (ed. J. Haury (Leipzig 1963) 261–62); Vegetius, *P. Flavi Vegeti Renati Epitoma Rei Militaris* (ed. Onnerfors (Stuttgard 1995) 34, 76–77, 259).

[39] La Salvia (1998) extensively discusses the ancient sources and goes in detail on the productions of weapons, turning either to archaeological data, or to archaeometrical analyses.

[40] La Salvia (1998).

In order to distinguish between iron smiths and more specialised artisans, detailed archaeometallurgical research on surviving metal objects is almost always needed. This can verify the characteristics of raw material and the methods used in smithing. Amongst these one should note: quenching (the sudden cooling of the blade, necessary for all cutting tools); annealing and tempering (repetitive heating at a medium temperature, alternating with slow cooling processes, to obtain less hardness and more elasticity) and cementation or carburisation (the hot working of metal, in contact with carbon and organic materials to obtain greater hardness). The different methods and skill levels used in manufacture can be used to identify processes with different levels of specialisation. Formal typologies of the simplest objects (such as knives and cutting tools) that are not accompanied by recognition of these processes, can tell us very little about either the technical ability of their creator, or their value and practical aspects. Without archaeometrical analysis, similar objects with different characteristics can be mixed up together.

Conclusion

The overall picture that I have sketched here is obviously one of significant continuity of techniques across a dozen generations during the whole of Late Antiquity. This continuity does not exclude new and, in some cases, premature inventions (among which was cast iron), or the modification of some production methods, or the development of a noteworthy complexity, stimulated by the differences between East and West. The continuity seen in metal production technology depends largely on the very nature of the working of metal, which nearly always involves manufacturing a product designed to assist another productive activity, which continued throughout the period. Firstly, this concerns tools designed for agriculture—the context, *par excellence*, for the conservation of artisanal techniques—and also tools designed for manufacturers, who did not even slightly alter their tools over the centuries. Secondly, it concerns tools designed for armament, which continued to be important despite the decline of the professional army, armed and equipped by its own craftsmen, because of increasing militarisation; armament was a medium and an object of prestige, especially where military rank became a social goal, even for the upper classes of civil society. Thirdly, it concerns tools for building, which despite the crisis of the cities, still served limited monumental and vernacular construction work. Fourthly, it concerns tools for the production of personal clothing accessories and of domestic fixtures and furniture (from buckles to locks), which united style and function in different ways. Finally, it concerns tools used to produce symbols of prestige.[42] These symbols allowed different choices of style—in their turn attributable to ethnic, gender and income-related variables—but we have also to take into account the coming of Christianity, the concentration of the elites on small sites and the reduction, if not the disappearance, of a middle class.

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[41] For the macroscopic features of slag and the possibilities of distinguishing slag associated with smelting, from slag from refining, and slag from forging: see Cucini Tizzoni and Tizzoni (1992); Cucini Tizzoni (1999b) 151–58.

However, despite this continuity, the reduction of the scale of extraction activities is particularly noticeable. Reuse and recycling became more significant. Technical knowledge became limited to a few persons, more so than in other periods. Furthermore, the preservation of much of this knowledge seems to have been especially connected to the production of objects used to emphasise individual and social differences, which went beyond the strictly functional, in particular clothing accessories. It was not based on the survival of a large market for everyday functional goods.

Three Possible Research Directions

The phenomena discussed in this article obviously require further investigation, and to be placed in a historical context, which recognises regional developments and other complicated dynamics. Various research strategies are possible, among which at least three appear particularly promising, because they take into account the manner in which technical knowledge is transferred. Technical knowledge is by nature very conservative (only changing slowly). It is transmitted through apprenticeship in the workshop, and becomes a form of culture which distinguishes professional groups, especially when it is highly specialised.

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[42] On the regionality of dress accessories see Swift (2000).

A first possible research direction would seek to differentiate manufactures, by combining stylistic characteristics (formal typologies) with specific technical evaluations (marks that distinguish an artisan, or a group of artisans, such as the traces of a single pattern, the mark of a specific punch, etc.).[43] The best publications of this type of work have recently considered belt ornaments, and also statuary; but they would be possible in many other cases, either in a limited territorial sphere, or with syntheses on a larger scale.[44] This is a form of archaeology that can be applied to finished handmade goods. These are much more numerous than well-investigated manufacturing installations, or even secondary indications of production.

Thus, it is important to study consumer sites where the discovery of dress accessories occurs relatively frequently. From the study of these sites it might be possible to identify variability in the availability of metallic goods between different periods and between different types of site, whether urban or rural. This kind of study must take the context of the finds into account—for example when dealing with finds from funerary contexts or small hoards—in order to better estimate what the life span of an object was, as well as to produce better dating. Techno-typological studies can, moreover, clarify what skill one had to perfect in a given period in order to standardise production. This could help us to understand local situations in which similar objects occurred which could have been created by various workshops, or alternatively very different objects which were manufactured in a single centre of eclectic artisans.[45]

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[43] The definition of elementary gestures ("gesto elementare") obviously goes back to the fundamental work by Leroi-Gourhan (1977), partly resumed in Mannoni and Giannichedda (1996).

[44] For the ornaments of Lombard belts see Giostra (2000); for bronze statuary see Lahusen and Formigli (2001) who consider the history of an exceptional and long-lasting manufacturing tradition, together with artistic and technical aspects (from alloys and fusion methods down to the smallest details).

A second research direction concerns the quantification not only of production, but rather of the material in circulation, that was available to consumers and which characterised different social groups. This depended in part upon the life of different classes of metallic objects, which, as has been noted, could stay in use for many generations, either in the case of tools, or in the case of jewels and valuables. However, they could also deteriorate rapidly or be destined for short-lived consumption, for example, in a ritual deposit. It will be especially important, in comparing the data from production and consumption sites, to estimate domestic metal use and tools used for agricultural, artisanal and military activities. Certainly, this is the most difficult field of study and most of it has to be invented, by making use of research that has been done on other materials but adapting the approach, because metals could be recycled and had a longer life-span. Difficult, however, does not mean impossible, because both recycling and conservation can be studied, at least in part, starting from the analyses of single archaeological contexts: for example, by studying mining sites in order to detect the phases and intensity of exploitation, or by comparing the data from abandonment deposits and by recognising recycling practices and the duration of use of objects that passed from one generation to the next.

Lastly, but only because it is the most costly method to acquire data, one should not neglect archaeometallurgical research, on key sites and on manufactured metal artefacts dating from Late Antiquity. The actual state of research funding makes this research direction, at least in Italy, the least feasible, because it requires the use of complex specialist competences and interdisciplinary collaboration which cannot be attained outside properly focused long-term research projects. This highlights the importance of a number of pilot projects that are currently under way, such as those in Bienno (Lombardy),[46] or, for the Late Middle Ages, that focusing on Rocca San Silvestro, in Tuscany.[47]

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[45] On this topic cfr. Paroli (1994) who significantly re-examines material from old excavations, which he thoroughly assesses for informative potential.

[46] Cucini Tizzoni and Tizzoni (1999).

[47] Francovich (1991), Farinelli and Francovich (1994).

Yet, metallurgical studies cannot be properly conducted on a single-site basis, without considering territories as a whole. It is not helpful to have a few 'champion' sites producing information from which one cannot generalise; such information, whilst useful, is not normally conclusive, especially within a period of strong regional variation such as Late Antiquity. Only widespread and systematic assessment of minor indicators of production, visible in finished products, and the evaluation of the levels of production, can lead to the reconstruction of coherent local frameworks, in which the metallurgy of Late Antiquity and the Early Middle Ages can be properly assessed.

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GLASS IN LATE ANTIQUITY: THE CONTINUITY OF TECHNOLOGY AND SOURCES OF SUPPLY

Lucia Saguí

Abstract

Scientific research and a series of important archaeological discoveries in recent years have opened up new perspectives on the study of ancient glass. Glass production seems to have been organised on a hierarchical basis. The primary workshops, mainly concentrated on the Syro-Palestinian coast, prepared the raw material by fusing sand from the river Belus with natron from Egypt. The product was then sent in blocks to all secondary workshops, the organisation of which was less elaborate. Here work was limited to re-fusing material that had already been worked. The widespread commercial movement of raw glass from East to West seems to have only come to a halt in the 9th c., when the export of natron from Egypt stopped. Consequently, a different flux was used, which was incompatible with the oriental sand. The adoption of local raw materials in the place of natron meant that the management of the entire production cycle became gradually autonomous, at different speeds and in different ways, during the course of the Middle Ages.

INTRODUCTION

The aim of this paper is not to re-visit the long-standing debate between the supporters of historical continuity and those of a catastrophe theory. Rather, it simply seeks to underline what could be defined as the new direction in glass studies in recent years. In brief, this essay will not present anything new to specialists, who might consider it too basic or even premature, because glass studies are in continuous progress, with new discoveries constantly being made. Instead, this article intends to provide an outline of the main trends and most important research results in this field, with the intention of introducing late antique glass studies to a wider group of scholars. Although work in every specialism tends towards isolation, the insularity of glass studies has been exceptional in comparison with research into other archaeological materials;

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glass studies have often been characterised by a bias towards aesthetics, which has limited their contribution to studies of Early Medieval or late antique economic history. However, this article will review the elements that have opened up a new perspectives on glass studies, and seek to establish how the interests of scholars of glass studies can interact with those of ceramicists and, ultimately, with those of historians.

Raw Materials

In Antiquity, glass consisted of a mixture of a vitrifying substance and a flux. The former was silica, and was found as sand or siliceous rock; the latter comprised soda or potash. The flux, as its very name suggests, was necessary to lower the fusion temperature of silica, the normal temperature of which was around 1700 °C, much too high for the capabilities of ancient technology. The flux was capable of reducing the fusion temperature to 1000–1300 °C. In the sodium-flux mix, the sodium component could be obtained either directly from a mineral known in Arabic as, 'natron', or from plants which grew in the salty marshes of coastal areas. Salicorniae (saltworts) and tamarisks are examples of such 'halophytes'. Recent studies show that throughout the history of the Roman Empire, until the 8th/9th c., natron was the only flux used in glass production, and was only substituted by plant ashes after this time. From the Middle Ages, glass obtained from a potash mix—made from wood ashes—was not produced in the Mediterranean area, but on the continent.[1]

Natron and Egypt

But what is natron, and where was it found? Natron is a hydrated sodiumcarbonate, the largest deposits of which were found—and are still found—as crusts or efflorescences in the small lakes of an Egyptian depression, 8 m below sea-level, named Wadi an Natrūn. This area extended over *ca.* 50 km, consisted of 10 small lakes, and was located about 100–150 km north-west of Cairo (Fig. 1). Pliny reviews the sites where natron was found and gives a list of its multiple usages: he recalls,

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[1] On this type of glass commonly defined as 'wood glass', see Wedepohl (2000); Krueger and Wedepohl (2003); Stern and Gerber (2004); Wedepohl (2005).

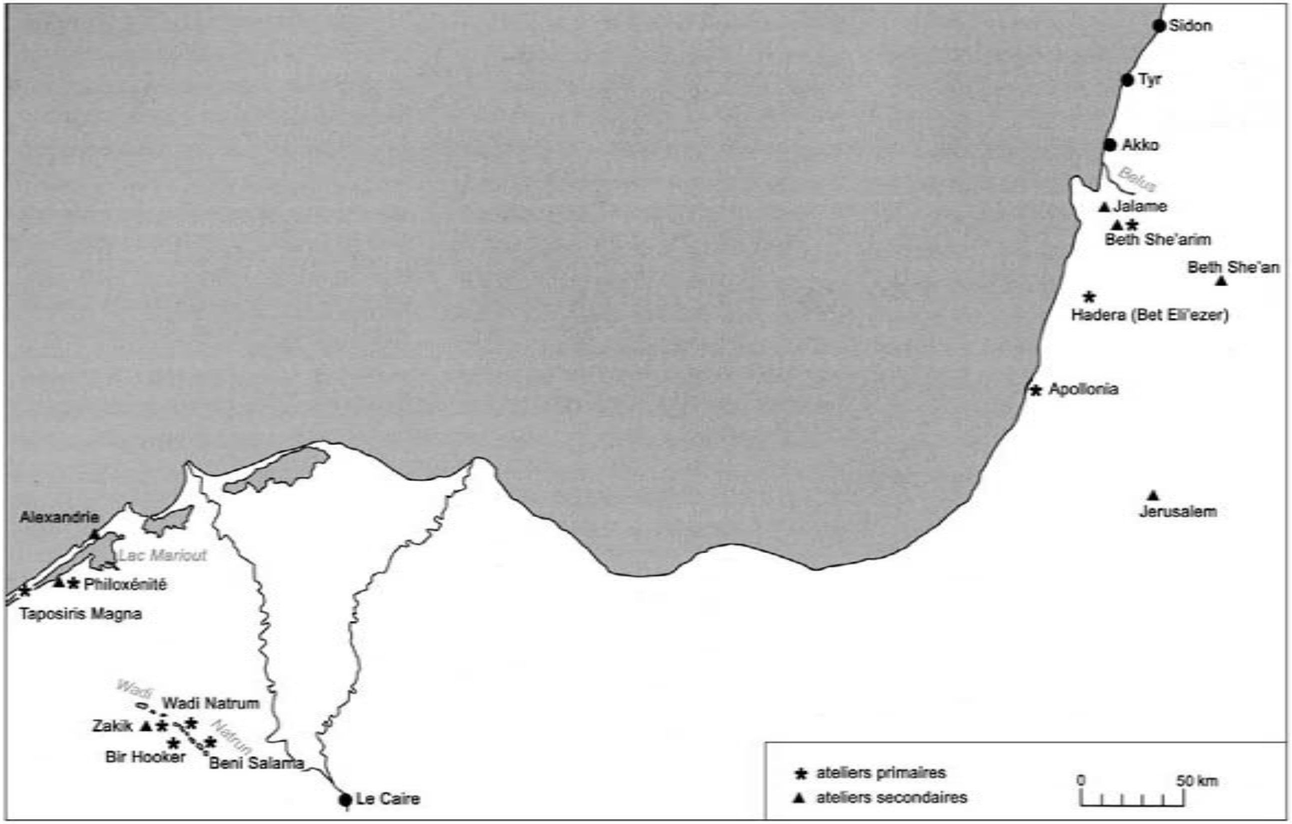

Fig. 1 The location of the Egyptian district of Wadi Natrun and the primary and secondary glass workshops in the Near-East. From Foy (2003b) 26.

besides the Egyptian sites, the modest deposits found near the Medes, and in Thrace, not far from Philippi, as well as those, of very good quality and quantity, in Macedonia, from which the famous *nitrum chalestricum* was extracted.[2] But, so far, there is no evidence to suggest that natron from these sites was used in the production of glass in Antiquity.[3] Thus it seems that the Mediterranean glass industry during Antiquity and up to the Early Middle Ages was entirely reliant upon natron produced in Egypt, together with other small centres of production.

The period of higher humidity which hit the Saharan area between the 8th and 10th centuries was quite plausibly one of the principal factors which altered the use of the flux and led to the adoption of wood ash. This is because it made the crystallisation of natron difficult and, therefore, greatly reduced its production.[4] Whitehouse has put forward the interesting hypothesis that the final blow to the tradition (almost 1,000 years old) might also have been the bloody 20-year civil war, which broke out in Egypt in A.D. 811 after the death of the Abbasid caliph, Hārūn al-Rashīd, and cut off the harbour of Alexandria from near-eastern glass makers for 11 years.[5]

Sand and the Syro-Palestinian Coast

Near-eastern glassmakers carried out the second key stage in the production process, the importance of which has clearly emerged in recent years. Hundreds of analyses and a series of important archaeological discoveries seem to converge upon only one result: that the largest quantity of natron glass in the Roman period derived from raw glass produced in the East, comprising natron from Egypt and sand from the Syro-Palestinian coastal area. The latter was particularly suitable, as it contained the right percentage of calcium, in the form of tiny shell fragments.[6] It was exported to a large extent, to both western and eastern glass factories. (This sort of 'triangular trade system' appears to have been the prevalent, though not exclusive, model in the Mediterranean area.[7] However, it seems certain that future archaeological research will unearth further production sites: for example, at Carthage, a furnace has recently been discovered that contained blocks of raw glass.[8]

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[2] Plin. *NH*, 31. 106–110. For Macedonian natron, obtained from a lake near the ancient town of Chalastra, perhaps the modern lake Pikrolimni, near Thessalonice, see Ignatiadou *et al.* (2005).

[3] For the use of natron regarding the production of glass, Plin. *NH* 36. 191–94.

[4] Picon and Vichy (2003) 30.

[5] Whitehouse (2002).

[6] It seems that in glass production, the use of calcium as a stabilising, anticorrosion element was unknown to ancient glassmakers, who were not able to select sand with the right percentage of this component: see Nenna, Vichy and Picon (1997) 84–85; Foy, Picon and Vichy (2000).

The analysis of some glass groups from the Early Imperial period and Late Antiquity indicate the use of sands of a different composition to the Syro-Palestinian kind. Most distinctive of these sands is that from the mouth of the Belus river (Ptolemais/Acre) and its surroundings. This research, still in its initial phase has, nonetheless, suggested that the most important glass group was an Egyptian group, labelled as 'HIMT' on account of its high content of iron, manganese and titanium oxides. This new glass composition is characteristic of the yellowish green to deep olive glass of the 4th–5th centuries.[9] Furthermore, recent surveys in Egypt have identified a series of workshops that produced raw glass by melting natron with local sands.[10]

There is no doubt, however, that primary production was concentrated in a restricted area of the East (Fig. 1) which was famous in Antiquity for glass production. It was centred on great centres such as Tyre and Sidon, to name but two. It is certain, then, that a hierarchical relationship existed between the production of glass and its working: two clearly distinct but mutually interdependent crafts.[11] The range of samples has been analysed to date in terms of provenance, chronology and quantity. The percentages of the 20 most important chemical trace elements—where their nature and content are concerned—show that the ingredients of the samples are remarkable uniform. This cannot be the result of mere chance, but instead illustrates the regular and consistent use of similar materials. This sort of 'chromosome mapping' can be seen in the sands of the Syro-Palestinian coast. At the same time, archaeologists have revealed a series of sites in the area, which were equipped with structures designed for the production of raw glass. For this reason, they have been defined as primary workshops.[12]

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[7] The production of raw glass that was not apparently destined for large scale trade, is documented in Germany in the Hambach forest near Köln, in the Danube area, and in Great Britain at York: Gaitzsch *et al.* (2000); Wedepohl, Gaitzsch and Follmann-Schulz (2003); Stawiarska (2005) 78.

[8] Foy (2003a) 88–89.

[9] Freestone (1994); Foy, Picon and Vichy (2000); Foy, Vichy and Picon (2000); Freestone, Greenwood and Gorin-Rosen (2002); Freestone, Ponting and Hughes (2002); Foy *et al.* (2003); Freestone (2003); Foy, Jézégou and Fontaine (2005); Freestone, Wolf and Thirlwall (2005).

[10] Nenna, Picon and Vichy (2000); Nenna *et al.* (2005).

[11] Stern (1999), particularly, 454–56.

Primary Workshops

Among the various production centres of the Syro-Palestinian area, that at Bet Elie'zer, near Caesarea, is particularly important. Here, 17 large rectangular furnaces have been discovered, dating from the 6th to the early 8th c. (Fig. 2). It has been estimated that each of these furnaces could have produced *ca.* 9 tons of raw glass at each firing. If one takes into consideration the whole structure, and assumes it was used only once, its productive capacity would have amounted to roughly one million finished vessels, weighing on average, 150 g each.[13] At the end of the process, which would have lasted about two weeks, the kilns were dismantled, so that large blocks of glass could be extracted. The structures were not permanent, but were worked until the available fuel in the area was exhausted. Following their abandonment, new furnaces were built nearby. Subsequently, these production centres, characterised by huge structures placed near to the source of supply, melted huge masses of glass, which were then broken down and distributed in the form of 'ingots' to the other centres. These centres required more modest plants, or secondary workshops, to re-fuse the already semi-crafted material.

Secondary Workshops

No primary workshop has been found that is more important than those scattered throughout the Syro-Palestinian area. However, outside of this region, thanks to the increasing awareness of researchers, more and more evidence of glass production is now being found: fragments of ingots, cuttings, proofs, crucibles, and mainly circular structures that

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[12] Gorin-Rosen (2000); Freestone, Gorin-Rosen and Hughes (2000); Tal, Jackson-Tal and Freestone (2004).

[13] Freestone, Gorin-Rosen and Hughes (2000) 67.

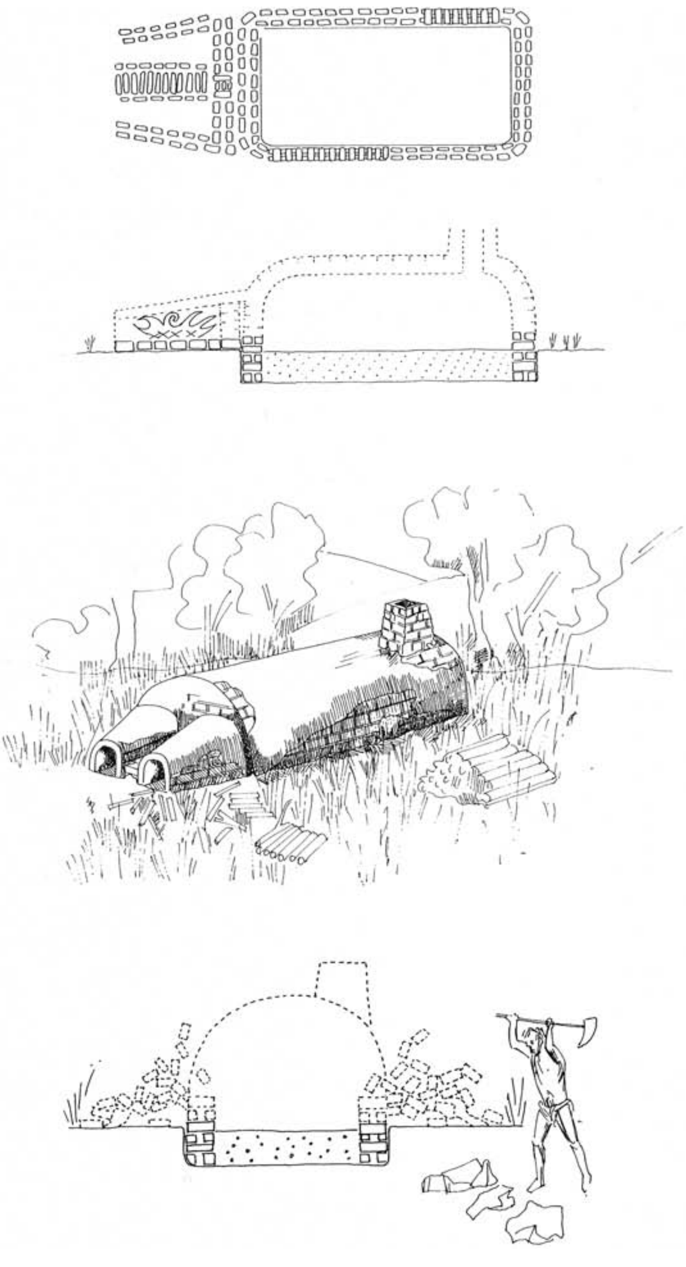

Fig. 2 Plan, sections and reconstruction of a glass kiln at Bet Eli'ezer. From Gorin-Rosen (2000) figs. 3–4.

are regularly less than diam. 1 m (Figs. 3–4).[14] Here, we are dealing with very modest kilns, designed to carry out the simple re-fusion of raw glass with metallic salts, or oxides, for colouring, bleaching, or inducing opacity. Such kilns would have also have been used to recycle glass (a fundamental component of ancient production), which resulted in huge savings on fuel, transport and storage. These small secondary workshops were closely integrated within the urban fabric. This was advantageous in that they were located in close proximity to markets where their products could be sold, and close to a supply of materials suitable for recycling. The tools that have occasionally been found near the plants, such as crucibles, were often made with ordinary coarse-ware ceramics, which had refractory properties. In northern Italy, archaeologists have recorded the use of soapstone vessels as crucibles.[15] But in general the crucibles are not very specific objects, as they did not have to resist exceptionally high temperatures as used in the original fusion process.

The similarity of these secondary workshops to the modest workshops still common in the Near-East today derives from the fact that they mainly used recycled glass. We have to take into consideration the fact that ancient glass production was carried out on a very small-scale, normally only requiring one individual, and that workshops were consequently very small and did not need to have more than one opening. Indeed, unlike other crafts using firing (such as pottery), glass production was never organised on a large scale in Antiquity. This was something that would only happen in Europe in the 15th c. Despite this, Roman glass was still a product that depended on an exceptionally developed technical expertise. The hypothesis that glass was traded from East to West is further substantiated by the discovery of several shipwrecks carrying ingots, and by the analyses of these blocks, which are frequently found among finds from secondary workshops.[16] Such analyses indicate

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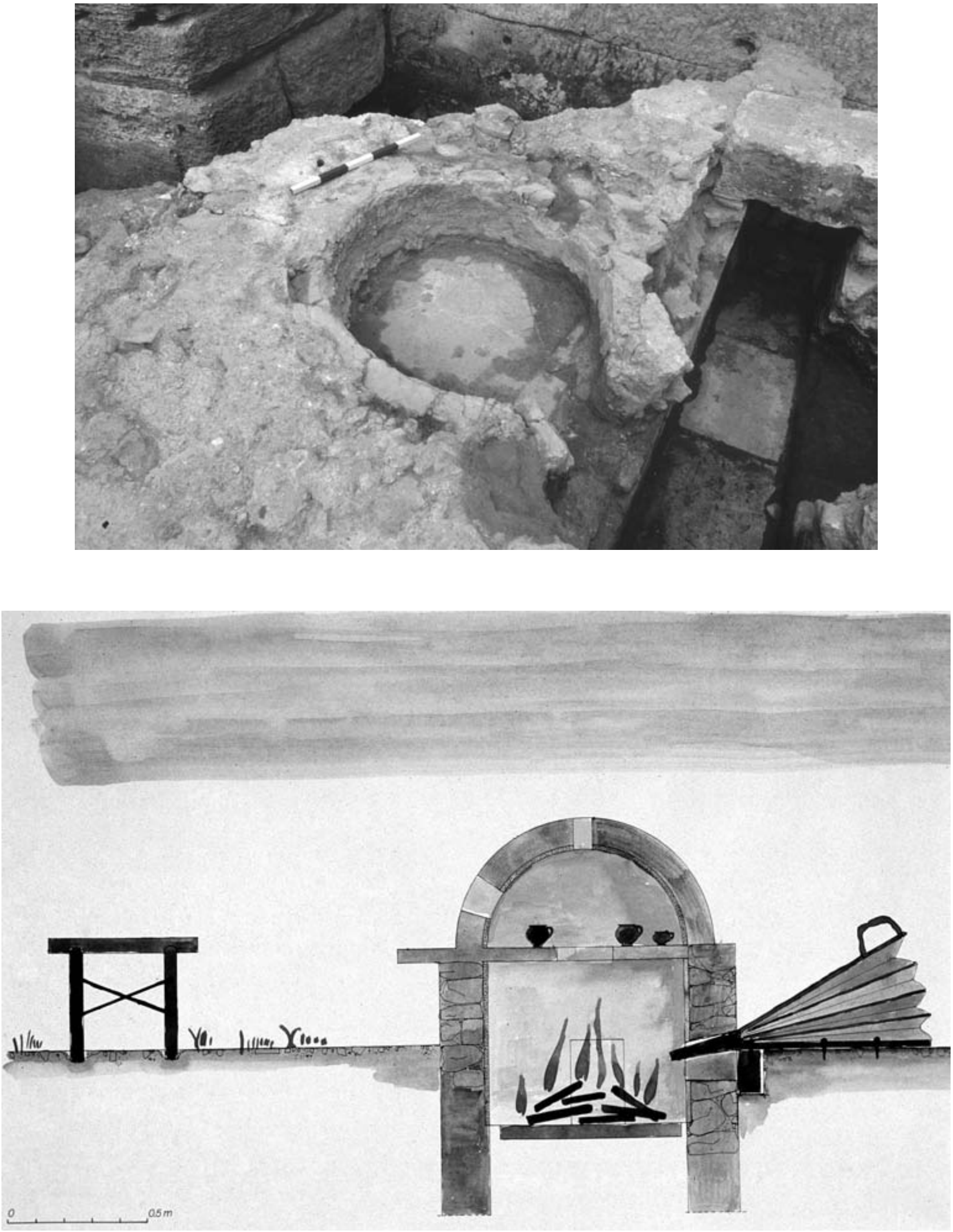
[14] For a review of the glass kilns in France, see now Foy and Nenna (2001) 47–60, and also Rivet (1992) (Aix-en-Provence); Pouille and Labaune (2000) (Cesson-Sévigné-Brittany-); Becker and Monin (2003) and Motte and Martin (2003) (Lyon); Munier and Brkojewitsch (2003) (Besançon); Amrein (2001) (Avenches); Albiach Descals and Soriano Sanchez (1989) (Valencia); Follmann-Schulz (1991) (Eigelstein), with a bibliography on the kilns in Köln; Tomanič-Jevremov (2004) (Poetovio); Saguì (2000) (Rome).

[15] Uboldi and Verità (2003) 120 and note 10.

[16] Foy and Jézégou (1998); Foy, Vichy and Picon (2000); Foy, Jézégou and Fontaine (2005).



Figs. 3–4 Rome, Crypta Balbi. Glass kiln (5th century A.D.) and reconstruction (drawing M. Cante).

that even the ingots found at Pompeii,[17] which presumably could have been made with sands from the Volturno river mentioned by Pliny, were in fact of eastern provenance.[18]

Technological Changes

A major technological change took place in the 9th c. (rather than in the 8th c.), as a consequence of the historical events mentioned earlier. This had repercussions for the organisation of production and on the wider economic framework in which glass was traded. It resulted from the fact that Egypt no longer exported natron. According to the near-eastern glass-working tradition adopted by the Islamic world, this led to a major shift: plant ashes, rather than natron, were now used as flux.[19] This development would not have had such important implications, had it not been accompanied by the use of different sands, and by the end, or at least the re-organisation, of what had been the great trade of raw glass from East to West and, consequently, by the end of the clear subdivision of work between the producers of the basic material and those actually crafting the objects.[20] Analyses of glass samples from this period, although not yet plentiful, are remarkably homogeneous, which indicates a more regular use of local raw materials.[21]

At the site of Bet She'arim in Israel, the exceptional discovery was made, of a huge glass slab weighing 9 tons. It had clearly resulted from a defective fusion and had, therefore, been abandoned. This is concrete proof that it was no longer possible to use the sand from the Belus River with the new type of flux. As more recent studies have indicated, this fusion was probably carried out using two incompatible materials: one traditional (the Belus sand); and one new (the flux from plant ashes) and unfamiliar to craftsmen. The outcome was a disaster, as the calcium content of the new flux was too high for it to be used with sands of this type.[22] In Byzantine Italy, the great turning point in glass production took place more than a century after the cessation of industrial and commercial practices typical of Late Antiquity.[23] Where pottery is concerned, this happened at the beginning of the 8th c., and resulted from an economic and productive system which was, by then, reduced to a regional scale. In the case of glass, this seems to have taken place during the course of the 9th c., when the great triangular trade systems between the East and the West came to an end and self-sufficient centres began to emerge. Thanks to the latter development, the entire production cycle of glass could be undertaken in one place; even if it did produce glass that was barely homogeneous in its composition.

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[17] Vallotto and Verità (2002).

[18] Plin. *NH* 36. 194. It is possible, however, that the use of Volturno sands had ended, or dramatically declined, by the end of the 1st c. A.D., as a result of contamination from volcanic eruptions: Vallotto and Verità (2002) 67.

[19] For a set of furnaces from this period, recently discovered at Tiro, as well as analyses of raw glass produced there, see respectively, Aldsworth *et al.* (2002) and Freestone (2002), with bibliography.

[20] Foy (2000).

[21] Uboldi and Verità (2003) 130–31.

Continuity and Change: New Data from Rome

The continuity of the glass industry during the Early Byzantine era is also clear from the repertoire of the shapes: shapes that appeared in Rome at the end of the 5th c. were still being produced in the course of the 6th, 7th, and 8th centuries. In the case of glass alone, a kind of *koinè* seems to have enveloped the whole Mediterranean area with forms of glass, such as the stemmed goblet (wine-glass) and the suspended lamp, being present in all areas, even if displaying a number of regional particularities. Figure 5 illustrates the chronological framework, which I was able to obtain from the examination of different contexts in Rome for the period between the 5th and the 8th centuries.[24] Two large contexts from the Crypta Balbi have played a fundamental role in this analysis, especially for the 7th and the 8th centuries. In all, they returned more than 15,000 fragments, among which were many indicators of production: ingots of raw glass, proofs, drops, cuttings, hollow rods of glass (moils), examples of rejects, glass drippings glued to the workshop floor, and hundreds of mosaic tesserae in multi-coloured glass, destined to be re-melted as colouring components (Fig. 6).[25]

The finished material is of the very best quality, and was evidently the result of an established tradition of workmanship. There is no evidence that the quality of this craftsmanship diminished in any way

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[22] Freestone and Gorin-Rosen (1999).

[23] Concerning the recently studied situation in Rome, see Romei (2004).

[24] Saguì (1993).

[25] On glass from the 7th c. deposit, see, in particular, Saguì (2001).

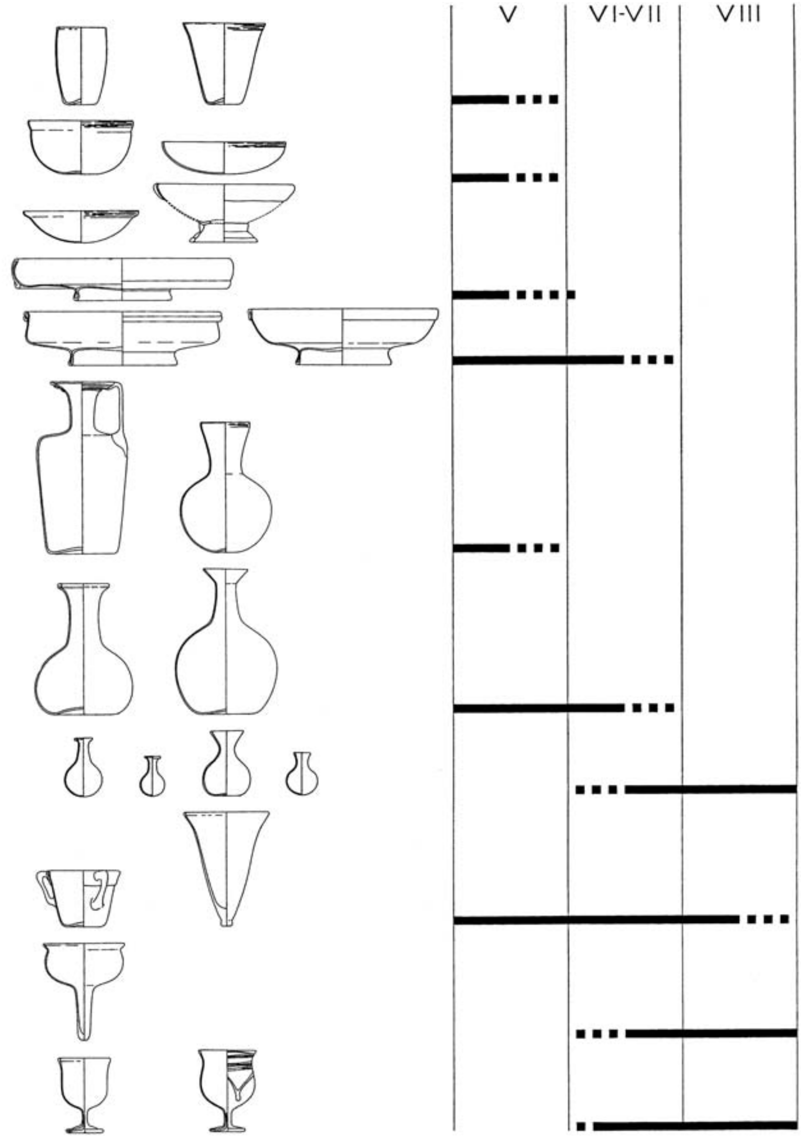

Fig. 5 The main glass shapes diffused in Rome between 5th and 8th c. A.D. From Saguì (1993) fig. 3.

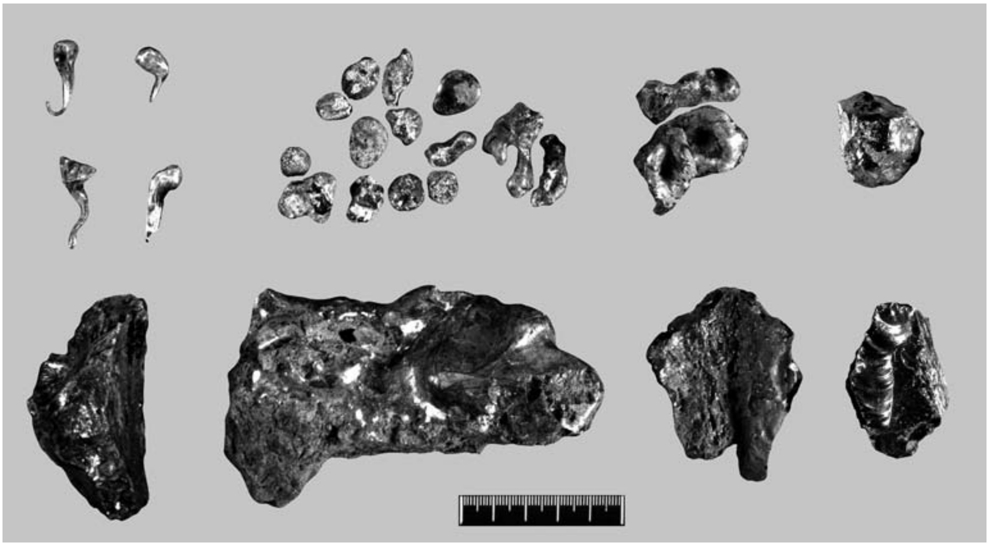

Fig. 6 Rome, Crypta Balbi. Indicators of glass production for contexts from the 7th and 8th c. A.D.

between the 7th and the 8th centuries, at least at a macroscopic level. Indeed, Prof. Mirti of the University of Turin used atomic-emission spectroscopy to analyse samples from both contexts,[26] which revealed a relative uniformity in technical procedure. However, his research also pointed to the more prominent use of recycled glass in the 8th c., which might reflect growing difficulties of supply. The workshops producing the glass of the Crypta Balbi were probably run within a monastic structure.[27] Indeed, ecclesiastical centres must have played an important role in this period in the continuation and diffusion of taste and technological know-how. Another example of the continuity of techniques and fashions to which the data from Crypta Balbi draw attention is the use of *opus sectile* in glass. This decorative genre was widely employed in the Principate and in Late Antiquity, and was still in use in the 7th c. A.D, as is shown by more than 200 small panels in different colours and cut in various geometric forms, which were

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[26] Mirti, Lepora and Saguì (2000); Mirti *et al.* (2001); Saguì and Mirti (2003).
[27] Saguì (2002).

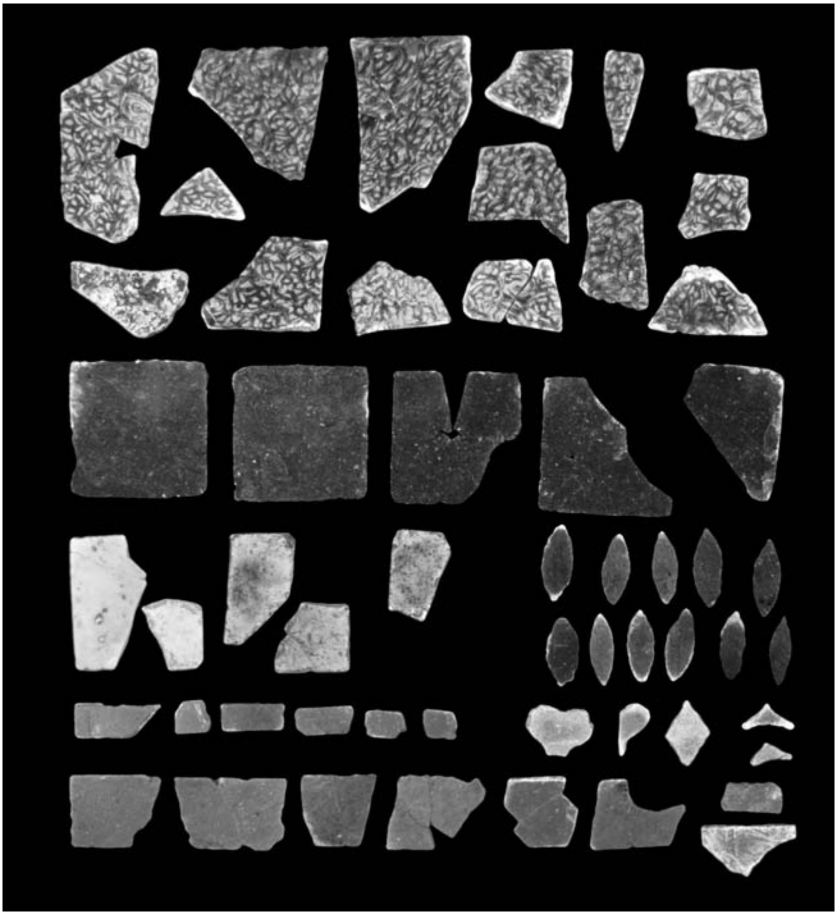

Fig. 7 Rome, Crypta Balbi. Panels in different colours, cut in various geometric forms, from a 7th c. context.

found in one of the Crypta Balbi deposits (Fig. 7).[28] Moreover, panels of this type, though scarce and associated with marble *sectilia*, are known in Justinianic religious buildings, such as the Euphrasian cathedral in Parenzo and St. Polyeuctos in Constantinople.[29] The column shafts of several contemporary churches in Constantinople were also decorated with glass panels, although these were inlaid works.[30]

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[28] Saguì (2001) 319–22.

[29] Terry (1986); Harrison and Gill (1986).

[30] Mathews (1976) 126, fig. 12.3 (St. Euphemia at the Hippodrome); 142, fig. 14.5 (St. John at the Hebdomon); Harrison (1986) 129–30, pls. 138–40 (St. Polyeuctos). For the

In the light of what has been said, it would be interesting to compare the archaeological evidence from the 7th and 8th centuries with that from subsequent centuries, in order to examine the transition to the new method of glass production. Unfortunately, despite much archaeological research in promising areas such as Rome, we do not possess sufficient data for such an analysis. This is not because there is a scarcity of contexts from these centuries in Rome: which are documented by tens of thousands of ceramic fragments;[31] but because these contexts are virtually devoid of glass samples. This phenomenon cannot be random, and can perhaps be explained—I believe—either by difficulties experienced in the re-organisation of the productive system, or by the widespread collection of glass for recycling, perhaps stemming from the demands of the contemporary production of the '*ceramica a vetrina pesante*' of the Forum Ware style, or by both of the preceding hypotheses.

However, evidence does exists for the organisation of urban glass production in the 10th c. A group of large crucibles was recently discovered, together with waste from bone-working in a well adjacent to the Crypta Balbi that had been used as a dump (Figs. 8–10). The vats are made from fired clay, revealing that they were specialised structures. Those examined so far—at least 5—are a similar shape, being characterised by slightly thickened, rounded rims, with rather thin, sloping walls, and flat bottoms. The outside surfaces are completely coated in a layer of clay (up to th. 2 cm), which constitutes a kind of veneer designed to protect the vat at high temperatures.[32] The inside is completely coated in a very thin layer of glass, gradually thickening toward the bottom. Although this analysis is ongoing, in light of what has been said thus far, it may be argued that these pieces were made with somewhat different ingredients to those used in previous centuries. But, we have to concede that this type of crucible seems to point to more sophisticated working structures, which were perhaps self-sufficient, and able to control the production cycle more closely.

The great archaeological context of the Crypta Balbi testifies to the the use of glass between Late Antiquity and the Early Middle Ages,

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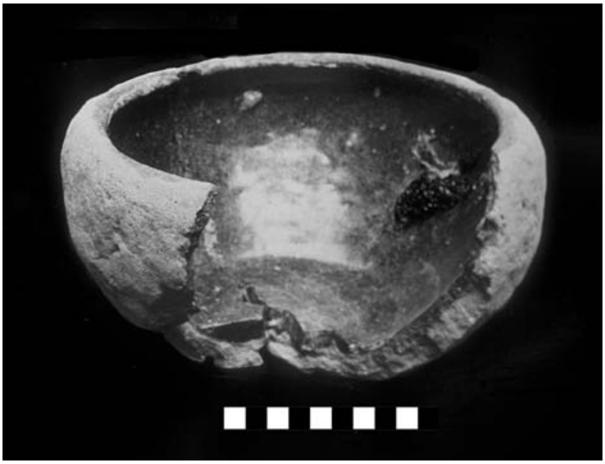
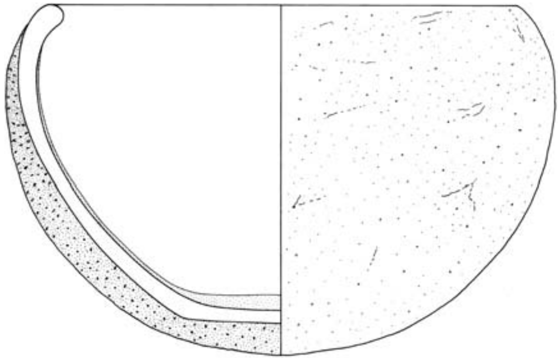
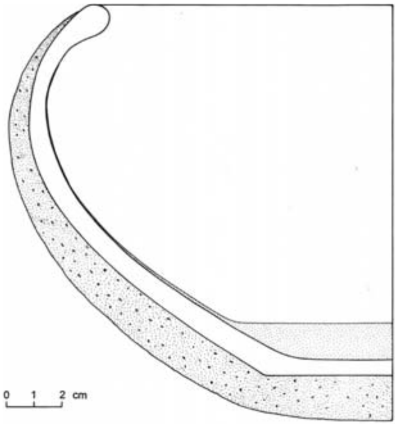
revival of this fashion of the precious facing of interiors in Constantinople between the 9th and 10th centuries, and on its diffusion, see Perria and Iacobini (1994) 141–43.

[31] Romei (2004).

[32] Crucibles like ours, dated between the 9th and the 10th centuries have been discovered in Toulouse: Catalo, Foy and Llech (1998) 15 ff. A very similar profile would also seem to have been characteristic of crucibles recently discovered in Naples within an artisanal context of the 12th–13th century: Carsana (2004) 30, fig. 12.







Figs. 8–10 Rome, Crypta Balbi.
Glass crucibles discovered in a late 10th c. context.

and the evolution of technological expertise in its production. The results produced here necessarily rely on a close interaction between two types of research: first, historical-archaeological work, focused on the analysis and interpretation of the contexts in which finished objects were used and, second, archeometric research, analysing the processes whereby raw material was transformed into finished objects. The latter requires the accurate physical-chemical determination of the components, the identification of the different areas in which these components were found, and a knowledge of techniques of primary and secondary production.

These areas of research will provide the basis for the considerable work which lies ahead. Above all, new developments in archaeometry constantly need to be brought to bear on historical interpretations. Indeed, attempts to draw definitive conclusions are quite impossible during a phase of scholarship in which the continuous development of archaeometry is transforming our knowledge with such rapidity. This is apparent from a quick glance through the latest volumes of the review, *Archaeometry*, and the *Proceedings of the XVII Meeting AIHV* (Antwerp, September 2006). The vast amount of ongoing research on this subject is enough to create a sense of disorientation in many scholars. Thus, in place of a conclusion, I would like to express the hope that historical work remains vigilant, thorough, and capable of drawing upon and interpreting a wide-range of types of research.

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GLASS IN LATE ANTIQUITY IN THE NEAR EAST

Margaret O'Hea

Abstract

This paper seeks to explore some of the possible connections between three late antique strands of glass technology and application in the Near East: windows, lighting, and finally, recycling. Glass has long been acknowledged to have influenced two major innovations in the use of internal space within the Roman world: firstly, during the Principate, when window-panes were first applied to bath-houses to maintain humidity and temperatures, whilst casting light into dark interiors, and secondly, in the 4th c. A.D., when oil-lights made of glass were finally adopted as an effective medium for ceiling-lighting.

Windows in Late Antiquity

When the archaeological evidence for the widespread application of glass panes in the early Empire is examined closely, 'innovation' becomes less apparent. Ward-Perkins used the unusual frames of the *Casa dell'Atrio a Mosaico* as an example of the ability of glass windows to highlight external views in architectural design, as well as change the way in which urban houses were designed so that window glass became common as a street-front device during the 1st c. A.D.[1] Other than in bathing-wings, however, there is as yet no overwhelming evidence that window-panes were widely used at Pompeii, Herculaneum, or at Ostia. Their earliest use in bath-houses seems to support this idea, as indicated by the comments of Seneca and Pliny the Younger; neither were they used to 'open up' street façades, nor were they normally used for external domestic windows. Examples of the sporadic use of glass by the Early Flavian period beyond bathrooms—as in the

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[1] Ward-Perkins (1981) 187, 193.

L. Lavan, E. Zanini, and A. Sarantis (edd.) *Technology in Transition A.D. 300–650*
(Late Antique Archaeology 4 – 2006) (Leiden 2007), pp. 233–248

tiny window of the lunette in Room 5 of 'House I.8.14'—are simply occasional exceptions.[2]

The fundamental problem in demonstrating this point is that much of it depends on an argument from silence, however. Since window-glass falls between 'architectural fittings' and glass typologies, it has been under-represented in modern archaeological publications. For example, a recent detailed discussion of the *Casa dell'Atrio a Mosaico*, describing construction technique, decoration and all available citations of artefacts, left out the remarkable set of rectangular glass panes supposedly set into a wooden frame down the eastern passage of the main courtyard, because they were not listed in Scatozza-Horlich's masterful catalogue of Herculaneum glass—which dealt only with vessels.[3]

We can, nevertheless, dismiss the idea that the absence of window glass from thoroughly recorded sites could be due to ancient recycling, or the vagaries of artefact survival. As anyone who has broken a modern window knows, glass window shards are difficult to remove entirely. In Antiquity, when we know anything of window glass, it was fixed somehow into the window aperture. Boersma's thorough survey of surviving architectural material at Ostia, including well-preserved walls, marble revetments, and stucco, did not mention one fragment either of a window pane, or of surviving plasterwork around window frames.[4] This particular case is surely not one of omission, but of 'real' absence. One can be less certain of the lack of references to window glass from sites such as Zeugma on the Euphrates: this site was destroyed in the mid-3rd c. by the Parthians and so unlikely to have retained any architectural features in its collapsed and destroyed houses.[5] Yet, the use of window-panes at the extremely well-studied site of late antique Ostia seems restricted to bath-houses.

Most urban or rural Roman-period sites have suffered from processes of abandonment, re-building and subsequent ploughing, or levelling, which has resulted in a dispersion of artefacts. This also means that, where window-glass is recorded on these sites, it is difficult to determine exactly which rooms it came from. Because villas, as well as military camps, tended to have bath buildings or bathing-wings, the simple 'presence' on these sites of window glass still cannot be taken to mean that glass windows were commonly used across the building complex.

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[2] Berry (1997) 191.

[3] De Kind (1998) 131–38.

[4] Boersma *et al.* (1985).

[5] Kennedy *et al.* (1998) 129–38.

The Evidence for Late Antiquity

In the Levant, there is surprisingly little published evidence for window panes in any Early Roman houses, regardless of whether domestic houses were built in stone or in a mixture of stone and mud-brick superstructure. The huge amount of debris from the city-dump south-east of Jerusalem, whose *terminus ante quem* is only nine years before the end of Pompeii and Herculaneum, and which must have included debris from the levelling of the city, has not yielded any identifiable window-panes.[6] Material from Early Roman houses elsewhere is lacking—and again, there is no word of any from Masada, although the final report is still to come for the glass.

But, in the 4th c., a third type (and second form) of window pane was developed.[7] The earliest technology created rectilinear panes by vertically cutting a blown, glass cylinder, which was then folded out flat into a rectilinear form; an alternative, pan-moulded technique, formerly thought to date to no earlier than the 3rd c., was probably also developed in the Early Roman period.[8] In the Early Byzantine period, however, circular panes began to be produced in the eastern provinces. They were simply blown as a very shallow plate, sometimes with a folded edge to them for greater strength where they would be plastered into a wall.

Their appearance begs a few questions. Why produce circular panes in the first place, especially since they were more difficult to insert into a rectangular or square window than rectilinear panes? Why did they appear only in the 4th c. (or later, if Carol Meyer is correct),[9] and why in a region that was probably *less* likely to be using window-panes than the western, or north-western provinces of the Roman empire?

Whether or not blowing a flat dish was cheaper or quicker than a pan-moulded, or 'muff' blown, cylinder is not easily demonstrable.

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[6] I am grateful to Dr Kay Prag for permission to publish the glass from Kenyon's excavations in Jerusalem. For the city dumps, see also Reich and Shukron (2003) 12–16.

[7] Harden (1939) 91.

[8] Allen (2002) 102–11.

[9] Meyer (1989) 213–19.

Those circular panes that I have catalogued seem, on average, probably lighter than the more uniformly thick rectangular panes, and their average size was probably the same (circular panes in the Levant tend to be diam. *ca.* 30 cm, compared with rectilinear panes from Sardis of 30–40 cm). The A.D. 301 *Price Edict* from Aphrodisias listed window glass at 8 *denarii* per pound, with 'second quality' window glass being two *denarii* per pound cheaper.[10] Whether or not this list reflected a real set of prices used by glass-sellers, it is reasonable to assume that the comparative worth of the various types of glassware recorded within the *Price Edict* was fairly accurate. The same text gives us the prices of glass tableware as well. From this, it is clear that window glass was, depending on its 'quality', two-thirds to half the price per pound of ordinary glass tableware. As circular window-panes were made in exactly the same way as shallow bowls or dishes, it could be speculated that they would be closest in value to tableware in price and, therefore, that the circular panes were the more expensive quality mentioned in the *Edict*. Alternatively, however, heavier rectilinear panes might have been the more highly-priced category, if weight rather than production-time was the decisive factor.

The Levant was devastated by a series of major earthquakes in the 4th, 5th, 7th and 8th centuries, as well as two major invasions, by the Parthians and then the Arabs. In the cities of the Decapolis, we have a particularly good sequence of collapsed mud-brick superstructures which, although levelled for subsequent re-building, preserved at floor level a good assemblage of household artefacts and architectural material. This can be studied along with re-deposited material from floor packing and rubbish dumps found elsewhere; this material provides some indication that Late Byzantine houses in Levantine towns seem to have had window panes more frequently than in earlier times. At Pella, this is supported by the presence of rectangular panes, in small amounts, from a house on Husn, which was built during the 5th or 6th centuries, without any bathing-rooms, and which was destroyed in the early to mid-7th c.; and also from a courtyard house, built originally in the Byzantine period, but destroyed in the mid-8th c. ('Pella North Building').[11] Circular panes are uncommon at Pella, only being used in some of the three churches there. Circular panes were, however, recorded from 4th–5th c. private houses on the 'Colonnaded Street' and from the élite 'House of Ganymede' at Samaria-Sebaste.[12]

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[10] Barag (1987) 114.

[11] I am grateful to Prof. J. B. Hennessy for permission to publish the glass from the University of Sydney's expedition to Pella, Jordan. For the dating of the Husn building, Watson (1993) 198–210.

That window-panes only became more widespread in Late Antiquity can, perhaps, be supported by the handful of published, excavated glass workshops from the region. The workshop from Jalame in the late 4th or early 5th centuries did not seem to produce window glass,[13] but panes were produced at a workshop of a similar date in the forum at Samaria-Sebaste,[14] and also one from Beth Shean from the Late Byzantine period (probably later 6th to early 7th centuries).[15] Samaria-Sebaste produced mainly circular panes, but the later Beth Shean shop sold both round and rectangular ones. It overlaps in date with 'Shop E12' at Sardis in Asia Minor, which stocked large quantities of purely rectangular glass panes at the time of its destruction in A.D. 616.[16] At Sardis, glass panes—which formed over 50% of the total mass of glassware on site[17]—were found within the area of the Bath-Complex and gymnasium/*palaestra*, as well as (mostly) within the street of colonnaded, two-storey Byzantine shops, which included 'Shop E12'. Such a disproportionate amount of window glass was explained by von Saldern in terms of the adjacent and grandiose synagogue, rather than the neighbouring bath-house, but it should be noted that the more recent publication of the synagogue is silent on the subject of glass windows in its detailed reconstruction of the synagogue's interior, its lighting and its fittings.[18] The reconstruction of the upper façade of the line of shops which backed onto the synagogue and bath-house, however, had ample room for windows.

Further south, in the Levant, private urban houses seem to have used at most only small windows in Late Antiquity, whether freestanding or within an insula. The central courtyards in many urban Levantine houses probably normally supplied enough daylight. At Pella, for instance, there is scant evidence for large apertures in walls, and the survival of many walls to more than 1.5 m without any openings suggests that windows were indeed both high and small. By comparison, window-glass from Byzantine Sardis seems only to have been used for the façade of the upper-storey of the shops, since they all backed onto the baths or the synagogue.

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[12] Crowfoot (1957) 419, 417.
[13] Weinberg (1988).
[14] Crowfoot (1957) 405.
[15] Mazor and Bar-Nathan (1998) 27–28.
[16] Hanfmann (1983) 164.
[17] von Saldern (1980) 91.
[18] Hanfmann (1983) 169.

According to the same evidence, a view from a glass window remained seemingly unimportant for Late Roman and Byzantine domestic architecture in the East. We do not have ornate *triclinia* at Pella, but at Petra, an élite 4th c. house on the outskirts of the city has yielded a *triclinium* with artefacts *in situ*, as a result of yet another earthquake. No mention as yet has been made in publications of any window glass, for the dining room seems to have been open, overlooking a slope.[19] Even at the Byzantine hot springs of Callirhoe, overlooking the Dead Sea, only two small fragments of circular panes came from the bath-complex. At the northern end of the complex was an open *triclinium*, but it looked east, away from the 'view' enjoyed today by visitors, and to the outcrops above.[20]

The use of circular panes—which, by their nature, could not be opened, as they were always set into plaster within a larger rectangular, or arched, aperture—perhaps also mitigated against the development in Late Antiquity of the hinged window. A window that could be opened went against the earliest use of glass panes in bath-houses, where they were used to keep in the humidity and help maintain stable internal temperatures, and this remained the case for late antique bath-houses, too, such as the 4th–5th c. *thermae* beneath the Early Islamic mosque at Jerash.[21] But in private Levantine houses, cool breezes as well as ample light might have helped regulate internal temperatures. Allowing a view outside was, as has been said, not an issue here. Yet glass windows that could be opened did *not* develop in Late Antiquity, as far as the evidence shows, and circular, fixed panes continued in domestic use into the early 7th c. at Beth Shean, and rectilinear ones at Umayyad Pella.

So, if glass windows did not serve to open up an external view, or allow much of a breeze, then why did they spread in late antique domestic contexts? The use of glass panes in bath-houses kept in humidity—surely not something wished for in a Syro-Palestinian summer. What could have been the key to their gradual introduction into ordinary houses? I would suggest that this occurred for the same reason that private houses used glass oil-lamps in the 4th c.:[22] the influence of church furnishings upon secular habits. The use of both circular and rectangular fixed panes in Levantine churches is almost too commonplace to discuss. The origin, in turn, of the ecclesiastical use of window-panes in basilicas from the 4th c. onwards probably leads back to that other major communal public building, the public bath-house, although it is possible that pre-Constantinian synagogues might have featured windows before basilical churches. For the purpose of this paper, however, it is the impact from the 4th c. onwards of ecclesiastical glass upon private homes that is at issue. Let us, therefore, briefly look at the most significant technological innovation of late antique architectural fittings: the hanging glass lamp.

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[19] Kolb and Keller (2002) 279–93.

[20] Dussart (1997) 99.

[21] I am grateful to Assoc. Professor A. Walmsley for permission to publish the glassware from the University of Copenhagen's Islamic Jerash Project.

GLASS LIGHTING

The innovative melding of two previously extant technologies—oil-lighting and glass-blowing—to create the glass lamp had a major cultural impact upon late antique writers, starting with the famous *Cathemerinon V* of Prudentius in the late 4th c.:

> With lights (*lychnoi*) sprinkled with rich oil or from dry rushes we feed them (fires), and we make rush-tapers (*scirpea*) too—smearing them with the flower-scented wax of the combs after the honey has been pressed from them.
> However we feed it, the little flame grows: in a clay dish with oil and a linen wick
> or on pine knots dripping with pitch or on *hemp* that draws the warm wax up so that the flame can drink...[23]
> So with thy gifts, Father, do the atria shine with noble flames, and when the day is gone the emulous light simulates it.
> The lamps hanging by swaying cords from all over the roof blaze brightly, and the flame fed by that in which it swims languidly shoots light though clear glass.
> The place of our prayer is so brilliantly lit that one might think the stars of Heaven itself were burning there in the ceiling...

The glass oil-lamp did not derive from pre-existing oil-lighting forms, but combined liturgical vessels and ritual lighting in a uniquely Christian format. To understand the roots of the glass oil-lamp, however, we must first digress on the subject of candles. In the Early Roman period, a *candela* meant both a simple rush-light, a reed that 'stripped of its outer coat...serve as candles and funeral lights',[24] and any cord covered with wax. As such, *candelae* in secular Roman texts can refer simply to reed torches, and their outdoor use reinforces this, as in Juvenal, *Satire* III, 85–86: '*breve lumen candelae, cuius dispenso et tempero filum*'. Such a meaning persists even in the Greek author Athenaeus (a later compendium of Book 15 mentions a servant who buys *kandela*).[25] This double meaning—for waxed cords and reed-lights—may have given rise to the early Latin word *candelabrum*, denoting a metal stand for holding reed torches or waxed splinters (*ligna*), as can be seen by a quick glance at any Etruscan versions of these. They have tiers of spikes pointing downwards that might not have been used for candles, since they would have undoubtedly melted the candles above them. By the time of the early empire, *candelabra* from Pompeii and Herculaneum were, in fact, simply stands for indoor oil-lamps.[26] Even spiked examples, which appear from the Early Byzantine period, can hold metal lamps with matching recesses on their bases, simply to make them more stable.

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[22] Cf. Keller and Lindblom (2001) 379–82 for the Petra house.

[23] *Seu ceram teretem stuppa calens bibit.*

Although wax candles were, of course, known to the Romans, both archaeological and literary evidence confirms that oil lamps were *the* form of ancient domestic lighting, even for the poor, in the East or in the West. Moreover, certain evidence for domestic candlestick-holders before the 3rd c. is lacking. In the Roman period, the Jewish Sabbath *menorah* was a metal lamp-stand upon which oil-lamps sat; by the Late Roman period, synagogues could also hang the 'perpetual light', 'usually made of glass', above the *menorah*.[27]

Without exact evidence for the domestic use of Roman candles, we have to rely on literary texts and scant images of candles to understand their functions. The primary use may have been in pagan religious rituals, especially if these had a funerary significance. A mural of the 'Temple of Isis' at Herculaneum probably shows a priest holding an upright wax candle, not simply a normal way to illuminate the nocturnal scene, but in the particular context of the goddess Isis, whose *lychnapsia* (festival of lights) allowed initiates to re-enact her search for Osiris, using—according to the 4th Calendar of Philocalus—candles, torches and lamps.[28] A 3rd c. A.D. reference to an eternally-lit '*lucerna super candelabrum*' in a temple of Venus probably means an oil-lamp;[29] candles were not used within pagan temples for lighting, although, if the 3rd c. papyrus from the temple at Arsinöe is any indication, oil-lamps were used.

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[24] '...*detracto cortice candelae luminibus et funeribus serviunt*'. Pliny *NH* 16.70.178 (Loeb edition 1960).

[25] Loeb edition (1971) 267.

[26] Lista (1986) 180, nn. 61–62, inv 78485, 78537.

[27] Sussman (1983) 232.

Conceptually, both candles and torches seem to have been linked in both pagan and Christian Roman culture with funerals, and not with everyday life. Torches appear in tomb murals around the empire, presumably as both symbols and reflections of real practice for nocturnal funerary processions and visits to dark places: even Early Christian funerary images show torches, such as in the Christian meeting-house at Doura-Europus.[30] The earliest clear-cut depiction of candles dates from the 2nd–3rd centuries A.D., and also derives from a funerary context. A single mummy-case portrait from Hawara, now at Manchester Museum, shows a man holding in his left hand a lit candle, the lower part of which seems to be in a protective covering or cylindrical holder of indeterminate material.[31] A 3rd c. pagan tomb at Abila, in northern Jordan, seems to show lit candles sitting on stemmed, low stands,[32] as they do on the walls of the 4th c. tomb at Or ha-Ner.[33] A group of ceramic stands from late 3rd or early 4th c. tombs at Amman and at Rajib are said to be candle-holders, on the grounds that they have a 'drip-gutter'.[34]

A now lost mural from a mid-2nd c A.D. tomb at Soussa, in North Africa, shows a man holding a glass candle-holder before a stall selling drink by the glass. I cannot make sense of it unless there was an intentional link between the chalice-like candle-holder and the glass goblets used by the stall-holder (who surely would have had his own lighting!).[35]

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[28] Witt (1977) 92, n. 38–39.

[29] Lucius Ampelius *Liber Memorialis*: VIII. '…*Bargylo est fanum Veneris super mare; ibi est lucerna super candelabrum posita lucens ad mare sub divo [caelo], quam neque ventus extinguit, nec pluvia aspargit.*' (Ed. E. Woelfflin 1873).

[30] Rostovtzeff *et al.* (1936).

[31] Doxiades (1995).

[32] Smith and Mare (1997) 307–14.

[33] Tsafrir (1968) 174, fig. 3.

[34] Bisheh (1972) 82–83, fig. 3, pl. 3; Bisheh (1973) 66, pl. XL, 1.

[35] Reinach (1892) pl. XXIX and Yacoub (1988) 292, fig. 12.

Yet the goblets are clearly different in form from the candleholder. Two early 3rd c. Rhenish military graves actually contained glass candleholders in the form of two handle-less goblets attached end-to-end, one with an internal tube to hold the candle upright, rather like the wick-tubes in later Levantine handled, glass beaker-lamps.[36] The vestibule mosaic from Piazza Armerina, which might be late 3rd c., shows a lit candle held in a silver or glass, handle-less goblet, just like the Rhenish examples.[37] The subject of the mosaic is a mystery, but it is located opposite a household shrine in the garden, recalling Juvenal's Satire 12.[38] A 4th c. Mithraic tomb at Gargaresh, North Africa, also shows servants holding lit and thick candles in footed, but handle-less, glass goblets,[39] and lit candles on stands appear in non-Christian contexts; from a 4th c. dining room mosaic in the 'Villa Fortunatus', near Fraga, Spain,[40] to the Egyptian-style frieze under the *opus sectile* mosaic from the 'Basilica of Junius Bassus', Rome.

And so we return to the late antique church. On the one hand, the Christian calendar is dominated by two events, one of which concerns death and renewal. I suspect that the use of candles as ritual items—not as lighting—developed from the widespread and varying ways in which a number of pagan cults also used candles. By A.D. 303, a reference to *cereofala* in a Numidian church and 'two wax-light bearers' (*ceroferarii*) who walk before the deacon, clearly indicate wax candles, not torches, which were always a form of outdoor lighting. By the A.D. 380s, the Aquitanian pilgrim, Egeria, twice refers to explicitly portable '*candelae et cerei*', which were both brought into the *Anastasis* at night in the Constantinian Church of the Holy Sepulchre, whilst *candelae* were also carried in mass baptismal processions.[41] *Candelae* here clearly cannot be wax-tapers—these are *cerei* or *cereofalae*—and a clue as to their identity is also present in the same general description of the church: '*candelae* in glass hang everywhere and many wax candles are as much before the *Anastasis* as before the Cross and behind it'.[42] Since the *cereofala* were also portable, it was not the container that differentiated them. The conclusion must be that by the late 4th c., either '*candelae*' were now oil-wicked, glass hanging-lamps, or they were still wax candles, but somehow distinguishable from those explicitly described as waxen. The former seems the more likely explanation.

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[36] Follmann-Schulz (1992) 95, n. 56.

[37] Wilson (1983) 90, fig. 56.

[38] '...where my little images (of shining crumbling wax) are being decked with slender wreaths' (shrine to the Lares). Here all is bright; the gateway, in token of feast, has put up trailing branches and is worshipping with early lighted lamps (*lucernis*) ll. 85–92 (Ramsay translation (London 1918)).

[39] Romanelli (1970) 319, pl. 264.

[40] Tarradell (1969) pl. 173.

[41] Ed. P. Geyer (1898): 58.

It is possible that the Late Roman use of glass candle-holders in a pagan funerary and ritual context *may* have provided the impetus for the use of glass for oil-lamps. For practical reasons, having a lit wick leaning in a glass nozzle was not conducive to long-lasting lamps. Taking the candle-holder as a prototype, but using oil on water, with a floating but stable, clipped wick, glass goblets easily became lamps. As lamps, they appear in large numbers within Early Byzantine churches, such as at Anemurium.[43]

Once provided with handles, glass goblets were used for oil-lamps, and their potential uses rapidly expanded. Christian congregations for the first time held indoor nocturnal vigils and nocturnal baptisms, needing good indoor lighting for communal liturgy. The Constantinian basilica, which appeared in the 4th c., needed sufficient lighting for a mass of people, unlike most Roman public buildings or temples. Glass bowls could be hung in metal rings, incised to be viewed from below. And whilst metal suspension-lamps were well-known in the Roman world, they were limited by lighting only upwards rather than radiating light downwards through glass chalices, bowls and tumblers. Glass-handled goblets could be hung from tri-partite chains.

The well-documented iconography of the lamps on menorahs throughout the Roman period demonstrates well that synagogues took up glass lamps at roughly the same time as their appearance in Constantinian churches. From the 4th c., depictions of menorahs start to show tumbler-shaped glass oil-lamps rather than the standard ceramic or metal wick-lamp, although they never show goblet-shaped glass lamps.[44] The standing menorah over the niche on the synagogue wall at Dura Europos has tumbler-lamps on its arms which, if glass, are their earliest representation in art.[45] Hanging lamps with ring-handles could be depicted on 4th c. tombs in Rome (Via Latina, cubiculum E).[46] Whilst Christian candles from the 4th c. onwards continued to be hand-held (for example, the figure on the ceiling of the 'Crypt of S Cecilia' in the catacombs of St. Callistus), or placed on floor-stands (as with funerary mosaics of the pious in North Africa),[47] hanging goblet-lamps filled with oil and water became part of the iconography of the illustration of churches for the next three centuries, on mosaics in the East, as well as in the West.

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[42] *Candelae autem vitreae ingentes ubique plurimae pendent et cereofala plurima sunt tam ante Anastasim quam etiam ante Crucem, sed et post crucem* (edition 1898: 73, 5).

[43] Stern (1985) 35–63.

[44] Negev (1967) 193–210.

[45] Grabar (1967) pl. 68.

With the use of handles, suspension became the major innovation of the Byzantine period. No metal or ceramic lamps of the earlier period, suspended from their rods, could match the symbolic and real effect of translucent glass hanging lamps. This innovation cannot be underestimated—from churches and synagogues, this lighting spread to bath-houses[48] and, within decades, to private houses. That this development began in the Greek-speaking East is not provable, but it is possible: the lack of a Latin form of the label *polycandelon* for the hanger for these glass lamps might itself indicate that this was not a western innovation. Venantius Fortunatus (admittedly a reactionary Latinist) would describe it only as '*lychnus . . . cuius vitrea natat ignis in urna*'.[49] Glass lamps never developed their own label—they were simply *lychniai hyalai*, as a 5th c. Oxyrhynchus church ostracon clearly shows.[50] But metal hanging holders for multiple glass lamps of the 4th c. needed a new term; and *polycandela* were definitely not multiple candle holders, but were very specifically filled with glass lamps.

Unlike window-panes, however, glass lamps quickly entered common domestic use, as 4th and 5th century houses from Petra to Sardis attest. They were commonplace by the time of the grand dining-room in the 'House of Bronzes' at Sardis, with its *polycandelon*.[51]

Moreover, in the Near Eastern provinces, the overall use of glassware—as vessels, lamps and architectural fittings—appears to have increased considerably in the Byzantine period. A number of Levantine churches have collections of broken glass which could be interpreted as having been collected for recycling. Yet again, it is possible to find an alternative explanation for these piles of glassware, without necessarily suggesting an increase in recycling in the Late Byzantine or Umayyad periods.

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[46] Ferrua (1991) 98, figs. 77 and 158.

[47] Van Der Meer, Mohrmann, Hedlund and Rowley (1958) figs. 356, 458 and 575.

[48] Cohen (1997) 396–431.

[49] *Vita S Martini* 4.689.

[50] Montserrat (1995) 430–44.

[51] Ellis (1997) 44, 48.

At Pella, the smashed window and hanging lamps collected in locus 70 within the *parvis* of the 'Civic Complex Church' were interpreted as debris from the A.D. 717 earthquake, that had not been cleared by A.D. 749 when the last major earthquake hit.[52] At Petra, the concentration was in a tower room on the far side of the forecourt.[53] Another pile was identified at Kharm al-Karak.[54] At Jerash, piles of glass were concentrated in a passageway between the 'Fountain Court' and S. Theodore's.[55] But if these were piled for recycling, why was the recycling not achieved? At the monastery of Deir 'Ain 'Abata (S. Lot) in southern Jordan, vast piles of half-melted and collapsed glass lamps and window glass must have been deliberately swept, not washed, into a cistern adjacent to and beneath the pilgrimage church. It was scarcely a convenient place for future retrieval, and—as at Petra, at Pella, and at Jerash—the point is, that they were not retrieved at all. At Pella, for instance, we would have to ask why it would take 32 years for glass to be recycled (and then not re-used in the end). At Jalame, which certainly *was* a glass workshop in the late 4th or early 5th c., there is no record of piles of recycled glass, only of glass chunks (broken bits of ingots) and piles of wasters.[56] Chunks and wasters were also predominant at the glass works at Beth She'arim.[57]

The clue to these piles of broken, ecclesiastical glass might be found in the *synthronon* of the 'Civic Complex Church' at Pella. There, the American team discovered that the rubble core of the secondary insertion of an odd *synthronon* into the central apse contained large amounts of smashed glass lamps, whose destruction must have belonged to an early phase of the church—after the 5th c., but well before the 8th c. This is an odd use of broken glass, but Smith's and Day's suggestion that it was, specially buried, and thus placed out of circulation by this unusual construction, seems plausible.[58] Could not the piles found elsewhere in churches have been similarly preserved *from* and not *for* recycling? If so—and this is just a hypothesis—then it might reflect the special significance of church glass fittings in the minds of the congregation and clergy in Late Antiquity. And could not this powerful effect of church fittings—such as the heavily symbolic 'heaven' of glass hanging lamps upon the imagination of Christian writers and church administrators—also have inspired emulation, beyond practical suitability or necessity? Perhaps glass windows slowly spread into everyday domestic use only through the strongly-visible example of churches, synagogues (and eventually, mosques), all of which had enclosed windows, either of glass or of thin gypsum. In other words, this could be one late antique technological innovation that filtered into general use because people were exposed to it in a religious setting: a fitting twist to the story of late antique glassware in the Levant.

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[52] Smith and Day (1989) 70.
[53] O'Hea (2001) 370.
[54] Delougaz and Haines (1960) 49.
[55] Baur (1938) 521.
[56] Weinberg (1988) 28.
[57] Vitto (1996) 115–41.
[58] Smith and Day (1989) 49.

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ENGINEERING

THE INFRASTRUCTURE OF A GREAT CITY: EARTH, WALLS AND WATER IN LATE ANTIQUE CONSTANTINOPLE

James Crow

Abstract

By the later 5th c. A.D., Constantinople was the greatest urban centre in the Mediterranean world. This paper considers three associated elements of the infrastructure of the city, each of which applied aspects of ancient technology: a first theme will consider the urban terraces which have only been studied in detail for the area of the Great Palace, but which represent a massive investment in the transformation of the built topography of the city; a second theme will examine the new Theodosian fortifications and suggest that these reflect a new level of innovation more often associated with the religious and civic architecture of the city; the third theme will briefly review recent research on the water supply and will identify major areas of continuity and innovation into the Middle Byzantine period.

Introduction

> The essential disorder of cities has at least two main origins. First, great cites are big cities, and bigness implies complexity. Villages get their water from wells or small streams, small towns from small rivers that happen to flow through them; they dispose of their wastes into the soil or into those same watercourses, without much bother. But big cities need much more water than that, more water than can ever be supplied by local sources: so they must impound their rivers to build huge upstream storage reservoirs, or bring water from distant river basins, or both. And then if they are not to be racked with epidemics, they must channel their wastes for long distances downstream, to distant purification plants well out of contamination's way.
> (Hall, P. *Cities in Civilization, Culture, Innovation and Urban Order* (London 1998) 612)

The ultimate 'new city' of Late Antiquity was Constantinople. However, in modern Istanbul we can hardly expect to experience that "evocative 'late antique' experience", described by Luke Lavan when recalling the

L. Lavan, E. Zanini, and A. Sarantis (edd.) *Technology in Transition A.D. 300–650*
(Late Antique Archaeology 4 – 2006) (Leiden 2007), pp. 251–285

excavated cities of the eastern Mediterranean, "where the site is preserved as it was in the closing years of Antiquity".[1] Unlike, for instance, Justiniana Prima, history and change have not left Constantine's city alone. For the urban archaeologist, the fragmentary state of current knowledge and the prospects for future investigation are depressing.[2] A further difficulty for both archaeologists and cultural historians is that the traditional approach to the historical topography of the city has privileged texts over structures and their spatial context within the "existing fabric of the city".[3] This paper is concerned with three aspects of the urban archaeology of late antique Constantinople—terraces, walls and aqueducts—all three of which can be described as part of the infrastructure of the city. They are examined to reveal the distinctive character of the new city as a rival and a successor to the old imperial capital. It will be argued that the scale and magnitude of these works reflects not merely a massive imperial investment but that they also draw attention to the innovative and distinctive technologies driven by different circumstances of time and place.

The term 'infrastructure' has a wide and developing range of meanings. It is most simply defined as the "underlying base or foundation for an organisation or system"; alternatively, it describes the basic facilities, services and installations such as transport and roads, and similar public works needed for the functioning of a community or society.[4] In this paper, the latter definition is preferred, although the breadth of the former meaning is implicit throughout. Studies of ancient technology have often focused on technological progress and inventions, which are seen to have demonstrated new scientific knowledge and their influence on novel mechanical devices and their applications.[5] Ancient writers, such as Vitruvius, who provide some of the key sources for our understanding of ancient technology, however, present a broader picture of 'infrastructures' under the heading of *opera publica* or 'public works'.[6]

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[1] Lavan (2003) 171.

[2] See the comments of Mango (1990) 10; Ousterhout (2000) 242. See however the extensive excavations in the Harbour of Theodosius from 2005–2007.

[3] Ousterhout (2000) 241–42.

[4] http://www.answers.com/infrastructure.

[5] See, however, Greene (2004) for a more nuanced consideration of technology in the ancient and medieval world. For the recreation and development of the hydraulic infrastructure in early modern Rome, see the important recent study by Rinne (2005).

[6] Vitruvius *de archit.* 1.5.1–8, city walls, Rowland and Howe (1999) 156–63; water supply, Vitruvius *de archit.* 8.6.1–15, Rowland and Howe (1999) 277–81; retaining walls Vitruvius *de archit.* 6.8.6–7, Rowland and Howe (1999) 265.

Terraces

Barely a century after the fall of Constantinople in 1453, Pierre Gilles provided the first 'modern' description of the Byzantine remains, which remains fundamental to our understanding of the city's topography and buildings. In the introduction, he draws attention to the differing topographic settings of Rome and Constantinople:

> It was not very difficult to distinguish the Roman hills, because they were entirely separated by valleys, but it is not as easy to distinguish those of Constantinople because they are joined at the top. Besides, their backs do not project in so mountainous a way as they do in the front; so I cannot better describe them than by calling them a continued ridge of hills, each divided by valleys.[7]

In contrast, the physical setting of Rome provides level ground or broad slopes for the major public spaces of the Forum, the later imperial fora and the developments on the Campus Martius, and a limited number of precipitous hills for temples and imperial residences, such as the twin peaks of the Capitol, or the Palatine. As Gilles clearly describes, Constantinople possesses a single high ridge extending from the Bosporus and the acropolis of Byzantium to the west. The 'mountainous' backs are the north-facing slopes falling steeply towards the Golden Horn, broken by a series of short parallel valleys, and the equally steep banks cut by the Lycus, falling towards the Sea of Marmara. A close-contour plan of the city (fig. 1) shows these features very clearly. In comparison, fig. 2 reproduces the map of the terraces within the city published in Raymond Janin's *Constantinople Byzantine*,[8] the principal record of a system of ancient land retention. It is largely based on the observations made by Ernest Mamboury and others throughout the physical transformation of the Ottoman city in the first half of the 20th c. They are represented on fig. 2 by a series of thick black, parallel lines across the steep slopes.

There are no ancient descriptions of these structural features of the city, and a recent account of the Byzantine street system dismissed

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[7] Gilles (1988) 19; see now Byrd (2002).

[8] Janin (1964) 7–8, map 6; a detailed plan of terraces in the area of the Tekfur Saray has recently been published by Stephan Westphalen (1998) fig. 2, based on Pervititch's map it shows for example the association of the terraces with the church of the Pammacharistos.

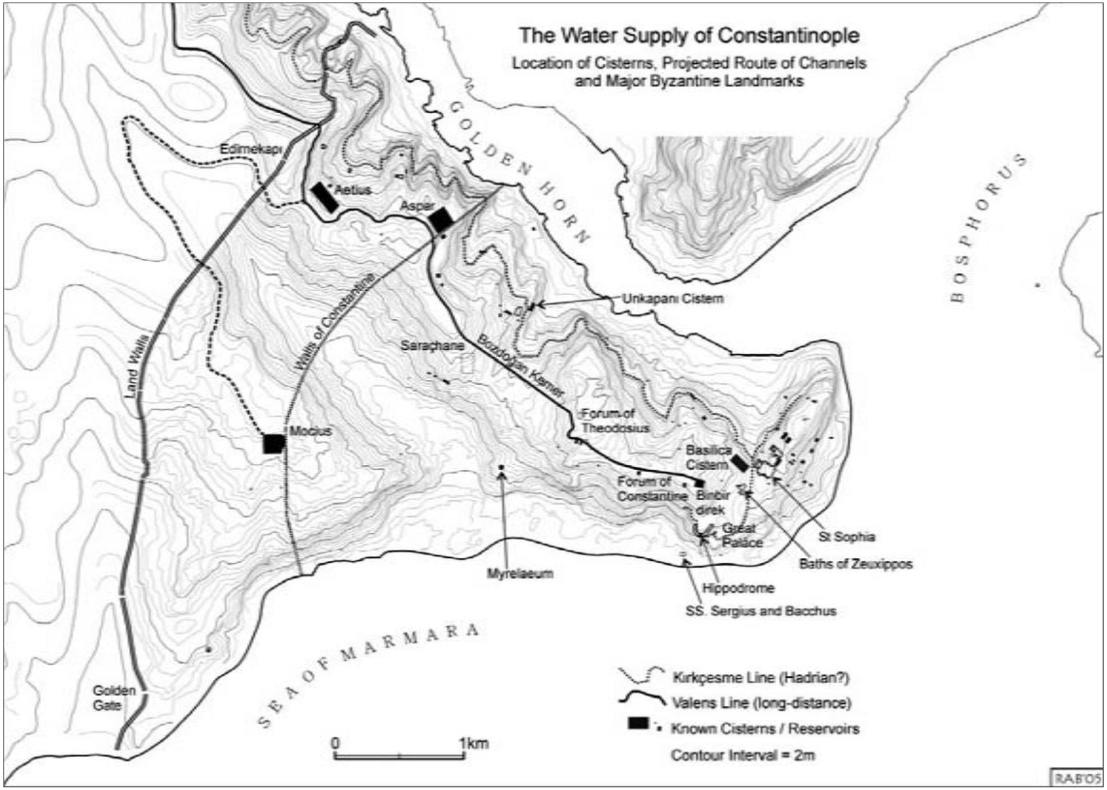

Fig. 1 Contour map of Constantinople showing the projected course of the two main water channels (Richard Bayliss).

much of this evidence as being largely Ottoman in date.[9] But in contrast, Bardill's detailed analysis of the brick-stamp evidence from the city specifically draws attention to the possible early date of brick terraces in the Forum Tauri, clearly demonstrating that terracing was an aspect of the urban layout from its earliest phases.[10] Certainly as presented in Mamboury's plan, it is possible to recognise potential areas of Ottoman activity, especially around the Eski Saray (the first Ottoman palace, now the area of Istanbul University) and the great Covered Bazaar. However, it is worth noting that they are included in the same area as the Sixth and Seventh Regions of the late antique city where the *Notitia urbis* attests to the highest density of domestic housing in the city and thus at least some of the terracing Mamboury shows may in origin derive from Late Antiquity.[11] Our limited understanding of the urban archaeology of the city has already been noted in the introduction,[12] so that much of what follows concerning the terrace systems is by nature 'informed speculation'. However, in some places, there is sufficient evidence for a secure late antique or Byzantine date for specific terraces associated with particular structures. On the basis of this secure evidence it is possible to predict that a very extensive programme of terrace construction formed part of the layout of the city from the 4th c. onwards.

In some areas, especially for the rectilinear alignment noted around the Column of Marcian and at the east end of the peninsula, in the areas of the Topkapı Sarayı and the Great Palace, it is clear that the majority of retaining walls were late antique in origin,[13] and represent a major effort in urban configuration. Mamboury provides specific insights into two aspects of the urban topography: in 1951 he divided the system of terraces into the maritime terraces above the Sea of Marmara and the Golden Horn and a central zone. He further noted

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[9] Berger (2000) 163; also Berger (1997) 404, n. 284; see however the reservations of Dark (2004) 104–05. Mango (1990) fig. 4 reproduces Janin's map of the Forum Tauri but does not comment on the terraces shown.

[10] Bardill (2004) 28. It is worth noting that much of this corpus is based on Mamboury's collection.

[11] *Notitia urbis Constantinopolitanae* in O. Seeck (ed.) *Notitia Dignitatum* (1876 repr. Franfurt 1962) 7–8.

[12] See n. 4 above.

[13] For the arrangement of terraces around the Column of Marcian, see Janin (1964) map 6; the forum is discussed by Mango (1990) 46; for the Topkapı Sarayı, see Tezcan (1989) and for the Great Palace, see a recent assessment of the evidence in Bolognesi (2002).

"D'autre part, dans la limitation de 14 régions et des 3 zones, la connaissance des terrasses, dont beaucoup abritent encore des citernes et de sous-sols, facilitera énormément l'étude de la topographie Byzantine".[14] Mamboury also considered the wider significance of the terraces and their broader urban context in his *The Tourists' Istanbul* (last edition published in 1953). His evocation of the form and structure of the Byzantine city may seem at odds with more recent studies of the historical topography—such as the current interpretation of the important term, *gradus*, which he understood only in its literal meaning of 'stairs'. But his account of the process of urban creation gives the reader both an insight into the problems faced by the builders of the new city and also a realisation of the impact of the topographic setting on the infrastructures of the new city, just like Lanciani's description of the rediscovery of ancient Rome in the late 19th c.[15]

> They (the great avenues of the city) were, as in ancient Rome, provided by sewers, which have been discovered at several points.[16] To lay out these great roads the tops of the hills were lowered and considerable engineering works were carried out. Much levelling was done and strong containing walls were built to contain level esplanades... Most of the highest ground was taken by cisterns or reservoirs, open or covered, or by a forum, in the midst of which there usually stood a column or a church. Unlike modern Istanbul, old Constantinople had few side streets or modern lanes, but on the other hand there were numerous steep streets of stepped slopes, which have attracted the attention of topographers in recent years. In the division of the town into fourteen regions in *Notitia urbis Constantinopolitanae* 52 arcades or avenues with porticoes are shown and 117 stepped streets. We are entitled to suppose that since the chronicler has given this information it means that these stepped ways played

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[14] Mamboury (1950) 445–46; the feature of the Byzantine cisterns abutting the terraces is illustrated in Tezcan (1989) endpaper; Müller-Wiener (1977) fig. 601; the association of terraces as *impluvia* for cisterns is noted by Wilson for Carthage (1998) 69.

[15] Lanciani (1897); for the context of these new urban excavations across Europe, see Çelik (1986) xvi.

[16] See Bardill (2004) 77–78, 110–11; Müller-Wiener (1977) fig. 288, shows the sewers A A and B B in cross section at the Forum of Constantine. The main literary reference to sewers is in the late text of the *Patria* 1. 69–70; ed. Preger II, 149, 'He (Constantine) also brought the aqueducts from Bulgaria, and he built sumptuous vessels (*karabos enkhorēgos*) all over the city that are as deep as the porticoes are high in order that there be no stench and no occurrence of many disease but rather that the stinking substances run through and run down to the sea. These as has been said were built by the praepositus Urbicius and the prefect Sallastius and the others, (Constantine) having left them six hundred kentenaria of gold for the porticoes and aqueducts and the walls.' (trans. Krausmüller).

> a preponderating [sic!] part in the circulation of the city. To obtain an idea of the topography of the city in the days of Theodosius II or of Justinian we must figure to ourselves a whole series of high and medium terraces running along the slopes of the seven hills like contour lines, arranged according to the locality in four, five and six levels laid out in the form of an amphitheatre. We must imagine... these terraces, often ten meters high, communicating with each other by means of stairways cut along the line of the steepest slope, connecting one main street on a lower level with one on a higher level. In this way, in spite of the often vertical steeply sloping ground, all private property was on horizontal ground and only the stairways were sloping.[17]

Unfortunately, the 117 'stepped streets' or *gradus* as they are referred to in the *Notitia urbis*, cannot be identified with flights of stairs linking the parallel terraces Mamboury envisaged; these are better understood as locations for the distribution of the *annona* and the bread dole.[18] Yet even if this textual connection is excluded, the evidence for the terraces still represents an important component in the creation of the distinctive urban fabric of Constantinople between the 4th and 6th centuries. As Mamboury's account makes clear, the public spaces and colonnaded streets, with the exception of the harbours and associated structures such as granaries, need to be located on the principal ridges.[19] Furthermore, given the size of many public structures, a system of terracing must have played an important role in the positioning of the major avenues and fora. They would also have been necessary to ensure the effective use of the urban space for domestic housing: a factor which may explain the long lines of terrace to the West, which are probably ancient, as they make little sense in terms of the layout of the Ottoman city.

On the terrace plan (fig. 2), the major concentrations are found in between the Forum of Theodosius and the Column of Marcian, on the steep, south-facing slopes near the Sea of Marmara. These include the 10th c. church of the Myreliaon, which was partly built on a pre-existing terrace, beside the site of a late antique palace.[20] A second group can be seen to be aligned around the Forum of Arcadius, extending a little way beyond the presumed line of the Constantinian Walls. Both

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[17] Mamboury (1953) 69–70.

[18] Dagron (1984) 533, Themistius *Disc.* 32, 292 a., uses the term εκράναι, translated as fence; see also Janin (1964) 45, n. 3. In Rome, however, the term *gradus* has the meaning of stairs, see Steinby (1995) 372.

[19] Magdalino (2000), Mango (2001).

[20] Striker (1981) 9, 11.

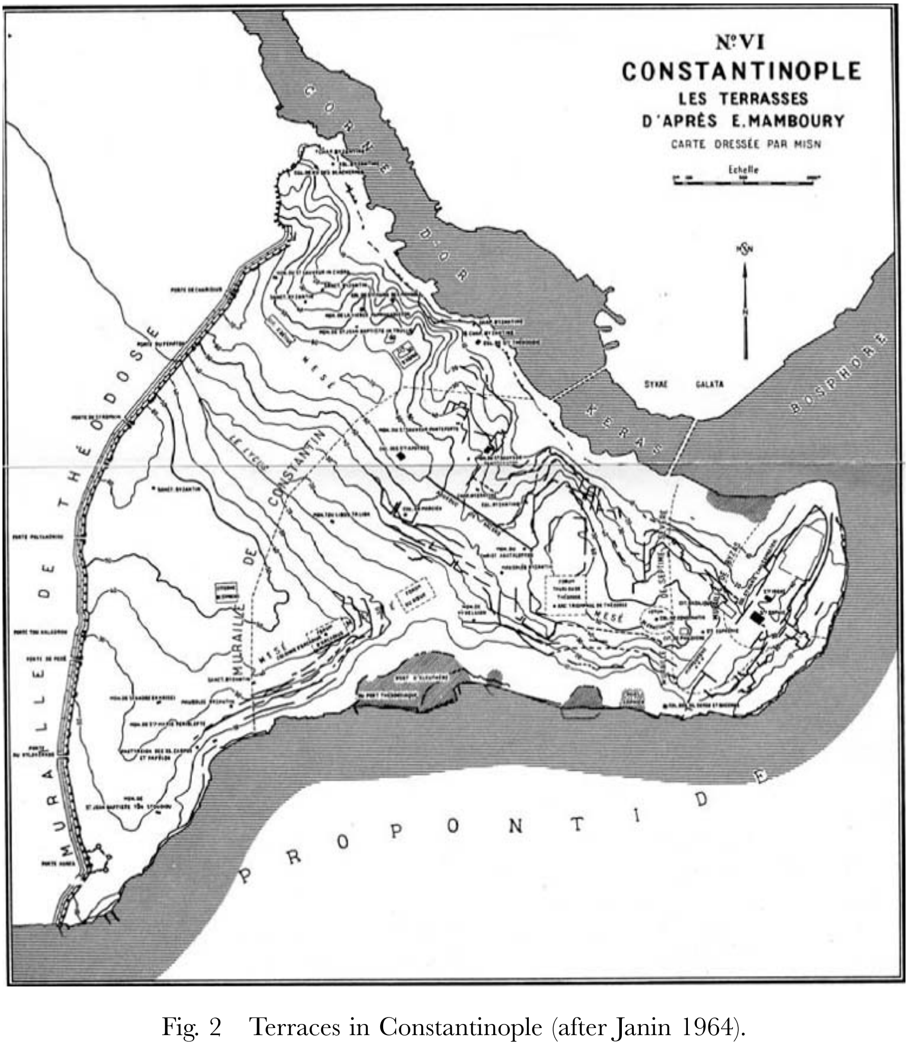

Fig. 2 Terraces in Constantinople (after Janin 1964).

groups represent up to four rows of parallel terrace walls, each extending over a kilometre and a half.[21] The walls near the south end of the Hippodrome and around the promontory have already been noted as part of the substructures of the Great Palace. These retaining walls can be seen to continue around the 'acropolis' of Byzantium, later occupied by the Topkapı Saray.[22] Despite the later works above many of these examples, they can be shown to be integrated with pre-existing Byzantine structures, including several cisterns, which are likely to be late antique in origin; a recent study of one terrace wall has identified it with part of the garden of the 11th c. emperor Constantine Monomachos at the Mangana Palace.[23] On the slopes facing the Golden Horn, the evidence is less secure and could well belong to the Ottoman buildings, as noted before. But in the vicinity of the Pantocrator monastery, beyond the broad valley crossed by the Aqueduct of Valens, further terraces survive, which may also be associated with the 5th c. cistern below it, near Unkapanı.[24] The external wall of this cistern indicates a close structural relationship between these retaining walls and the cistern, although the precise date of the terraces is not certain. From here to the west the only terrace walls marked are those around the Eski Imaret Camii and in the neighbourhood of the Blachernai.

Although some of the terrace walls may belong to Middle Byzantine and later Ottoman structures, it is possible to suggest that a significant number reflect the layout of the main southern and central areas of the Constantinian and Theodosian city. While it may not yet be possible to exactly relate the known terraces with road alignments, the terraces need to be recognised as a major element of the new city. Even if Mamboury was mistaken about his interpretation of the term *gradus* as connecting stairs, such stairs are still likely to have been a key element of the terraces overlooking the Sea of Marmara. Indeed, on his plan, a series of returns in the terraces, either cross-roads or steps, can be identified.[25] A recent survey of the archaeological evidence for domestic housing in Constantinople reminds us how very little we know compared to many other ancient and medieval cities. Documents like the *Notitia urbis* only provide evidence for the concentration of housing in certain districts, not for their nature or extent.[26]

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[21] Dark and Özgümüş (2004) 40–42, describe evidence for terraces at Cerrahpaşa, behind the harbour of Eleftheros.

[22] Müller-Wiener (1977) figs. 263, 601; Tezcan (1989) endmap.

[23] Maguire (2000) 261–62, identifies Middle Byzantine style brickwork in the retaining wall.

[24] See map and illustration in Müller-Wiener (1977) figs. 237, 244.

[25] See fig. 2, see also the plan reproduced in Mango (1990), fig. 4, showing Janin's attempt to relate these features to the Mese. This rather inelegant solution is not accepted in Mango's or Berger's discussion of the city's main avenue (2000).

In a subject where the topographical and historical reality is to a large extent grounded in the written sources, the absence of any reference to terrace construction has clearly inhibited their study. The sources on Rome differ and celebrate such building achievements,[27] perhaps on account of their unusual nature, since comparable terrace works were not required because of the physical setting of the older capital.[28] One extensive operation of earthmoving is known for the largest of the imperial fora, that of Trajan. In order to create a level site of such magnitude it was necessary to dig and quarry the spur of the Quirinal Hill, an operation which was demonstrated graphically in a recent study.[29] The construction of Trajan's Forum was the culmination of a process in the monumentalisation of Rome as the imperial capital. Such massive programmes may not have been acceptable under the Roman Republic, in contrast to the major terraced sanctuaries of the late 2nd c. B.C., in mid-Italy, at Praeneste and elsewhere.[30] Indeed, one of the causes for Julius Caesar's fatal unpopularity with the Senate was his grandiose scheme to remodel the Capitol as a great Hellenistic theatre, a project reminiscent of Pergamon and its terraced acropolis.[31]

But by the time of Trajan, Roman values had changed, and such projects could be the cause for epigraphic celebration. Thus, the final line of the inscription at the base of the column in Trajan's Forum has been interpreted to read, "in order to declare how deep were the rock and earth excavated for the great work".[32] While its meaning remains ambiguous, it is possible to recognise that Trajan's monument combined a cenotaph, a *tropeum* and a celebration of the engineering achievements, and however much historians might prefer the first two interpretations, it is the last that the inscription asserts.

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[26] See the discussion of housing in Dark (2004); for the *Notitia urbis* and a German translation, see Berger (1997); most accounts of domestic architecture are concerned with stone and brick structures, but both stone and timber houses are noted in Agathias' account of the earthquake of 557, *Histories* 5.3.1–11.

[27] See the recent analysis of 'exceptional construction' in the Roman world by Delaine (2002).

[28] Exceptions are the terracing along the banks of the Tiber, on the slopes of the Palatine and the major terraced platforms of the temples of Claudius and Venus and Rome. The works associated with Nero's Golden House will have involved extensive terracing, Steinby (1995) fig. 18. The most complex terraced structures were in Trajan's Markets and the great imperial baths, Delaine (2002) 211.

[29] Packer (1997) 447–48; Bianchi and Meneghini (2002) fig. 4.

[30] See Zanker (1989); Delaine (2002) 210, argues for Republican monumental construction although Praeneste does not figure in the examples she cites; Ganzert (2000) 46–47, provides an instructive sequence of sketches to illustrate the build up of the core monumental area of Rome from the 2nd c. B.C. to the time of Trajan.

[31] Suet. *Iul.* 44; Anderson (1997) 87–88, 212–13.

In Constantinople, a comparable text exists, celebrating both imperial military triumph and technological prowess. On the base of the Theodosian obelisk in the Hippodrome, the bilingual inscription in Greek and Latin is combined with a well-known relief depicting the triumphant erection of the monument.[33] In translation the Latin text reads:

> Of lords serene a stubborn subject once, bidden to bear the palm to tyrants that have met their doom—all yields to Theodosius and his undying issue—so conquered in thrice ten days and tamed, I was under Proclus' governorship raised to the skies above.

Unlike the Greek inscription, which is more prosaic,[34] this Latin text celebrates Proclus' ingenuity, as well as Theodosius' recent victory over usurpers (over the British usurper, Magnus Maximus)—the same event also celebrated on the Golden Gate in the Land Walls.[35] Both the imperial inscriptions of Trajan and Theodosius demonstrate the importance of the practical act of major engineering feats as a source of imperial prestige. Although the citizens could witness the performance of imperial triumphs and might even benefit from imperial largesse, these events persisted only through memory and artistic and literary commemoration. By contrast, the practical achievement of great monuments and buildings in an urban setting were a continuous reminder of imperial action and patronage; they were the essential features of the townscape, experienced daily by the dwellers of the late antique city. Such works were underpinned by major achievements of engineering and physical effort, terraces which sculpted the very ground of the city, and provided the settings for its hippodrome, palaces, piazzas and avenues.[36]

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[32] Packer (1997) 117; Steinby (1995) 356–59.

[33] Kiilerich (1993) 34, n. 99; Rebenich (1992).

[34] 'Only the emperor Theodosius dared to raise this ponderous square column, ever prone on the ground. Proculus was summoned and so it was erected in 32 days.' See Dagron (1984) 310–12.

[35] Bardill (2004) 29–30; see also the discussion in Delaine (2002) 214.

[36] The main avenue, the Mese, was longer than any other colonnaded street in the empire. Although Haas (1997) 29, 81–83, has rightly drawn attention to the Via

The Land Walls

Apart from Justinian's Great Church of Hagia Sophia and the 'Aqueduct of Valens', the most prominent surviving late antique monuments in modern Istanbul are the Land Walls, which suffered two decades of 'Disneyfication' by excessive clearance and over-enthusiastic restoration, with the notable exception of the project directed by Professors Zeynep and Metin Ahunbay.[37] Although the Byzantines later claimed that Constantinople was a city "Well guarded by God", it possessed the most elaborate and complex urban fortifications in the ancient world, thanks to the legacy of Theodosius I and his successors. The work on the extension of the city under Theodosius I commenced with the construction of the Golden Gate. It was completed by the time of the emperor's victory procession in November A.D. 391,[38] and as Mango has observed, "it seems obvious to me that the gate, with its massive pylons, was planned in the context of the new land walls, which for all I know, may have been on the drawing board already in the time of Theodosius".[39] The walls extend for 6.5 km from the shore of the Sea of Marmara to the Golden Horn. They were completed between A.D. 405–13, although the complete line of the Sea Walls would not be finished for another 25 years, probably in A.D. 439.[40] The chronology of the Land Walls has been subject to an extensive but sterile debate, which has centred on the interpretation of written texts, with little or no reference to the structural remains.[41] From east to west the Land Walls comprise four main elements: an inner wall, an outer wall with an inner terrace, a second outer wall alongside the ditch and the wide ditch (figs. 3, 4).

Canopica in Alexandria, the colonnaded streets of Constantinople were far longer, although the exact extent of the stoa is not precisely known.

[37] Recent work south of the Golden Gate under the direction of Professors Z. and M. Ahunbay (2000); unlike the walls of Galata which were demolished in the 19th c. A.D., the Land Walls were preserved despite major threats over the past two centuries. For changing attitudes to restoration and demolition, see Çelik (1986) 70, n. 97; for a sympathetic and innovative appreciation of the walls, see Costa and Ricci (2005), see especially 121, to indicate the radical restorations of the last twenty years.

[38] Bardill (1999) 690.

[39] Mango (2000) 179, n. 45.

[40] The date of the Land Walls has been recently discussed by Bardill (2004) 122; for the Sea Walls, see, Müller-Wiener (1977) 308–319; Mango (2000) 179, n. 41; the date is given in *Chron. Pasch.* 583.

[41] See Crow (2001); Bardill (2004) 122–25 provides full references.

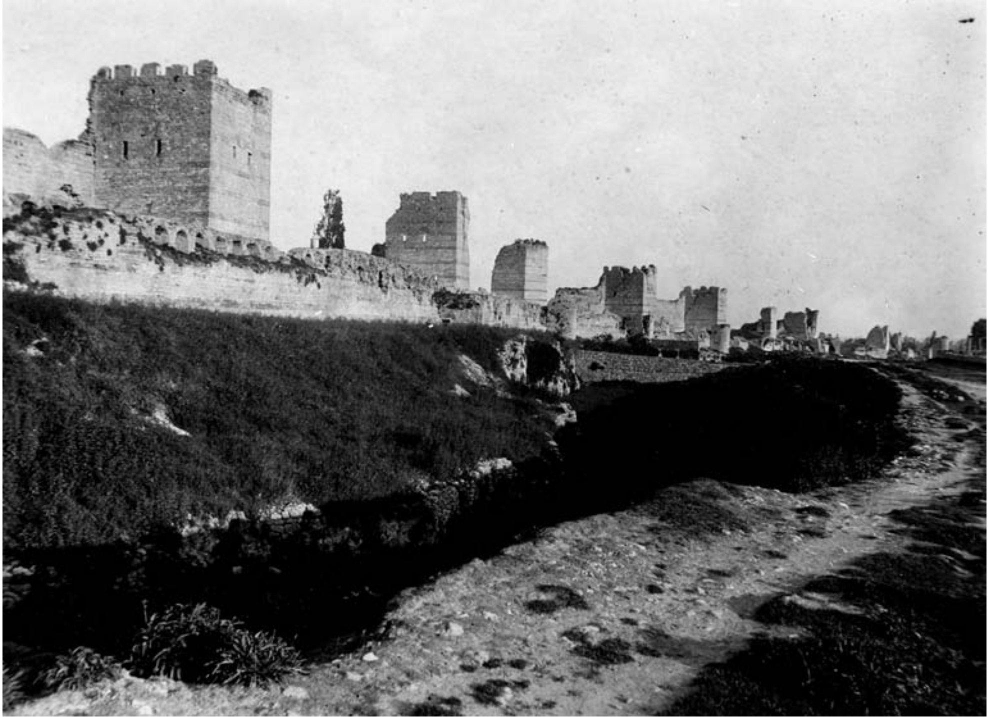

Fig. 3 The Land Walls of Constantinople showing the inner wall, outer wall and ditch (Sir Ian Richmond ca. 1930).

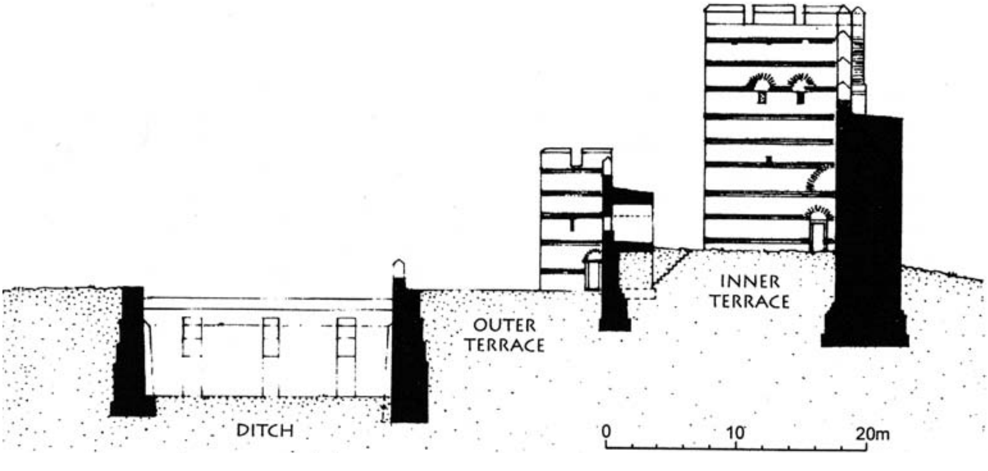

Fig. 4 Cross-section through the Land Walls (Richard Bayliss after Müller-Wiener 1977).

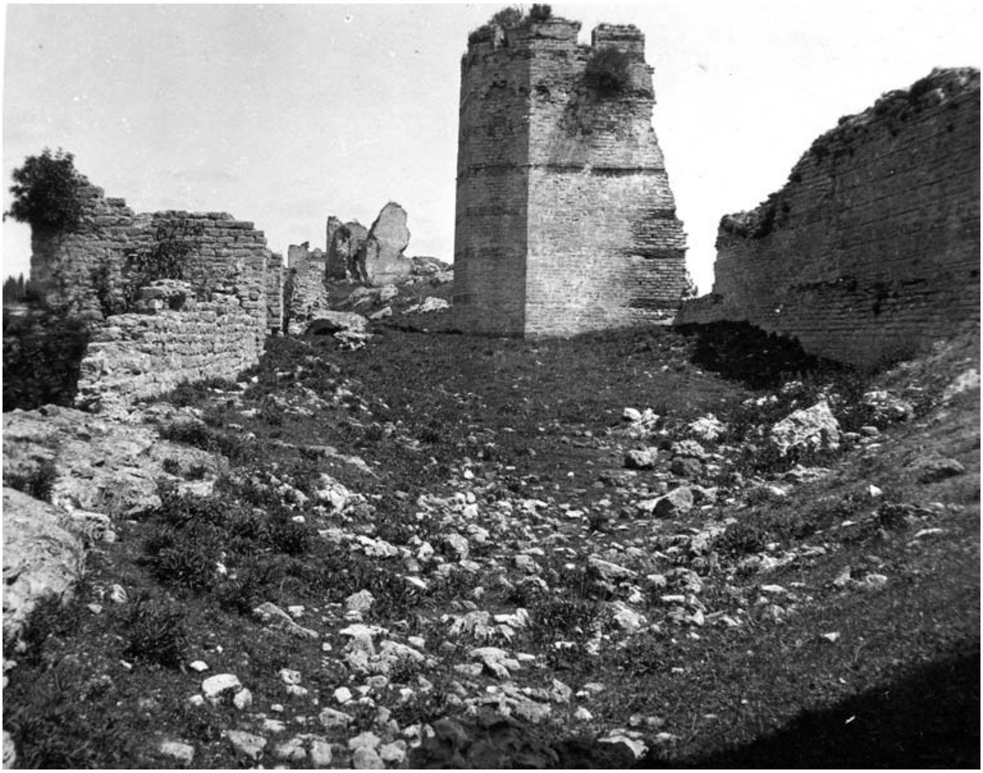

Fig. 5 The Land Walls, Tower 37, north of the Silivri Kapı and the level platform behind the outer wall (to the left). Recent excavations have revealed a hypogeum buried against the base of the tower in the inner terrace (Sir Ian Richmond *ca.* 1930).

The inner wall rises h. 9.8 m above the outer terrace formed between the inner and outer walls; on the inside, the inner wall rises up to 13 m above the ground within the city. The wall is w. 4.5–4.85 m, with towers 175–181 m apart, h. 19 m and projecting 6–11 m. On the ground floor are high vaulted chambers which normally had no access to the tower above. These last are specifically mentioned in a law of Theodosius II, demonstrating that they were allowed to remain in private usage as compensation for the land expropriated for the Land Walls. Presumably this principle can also explain the hypogeum recently discovered close to the Silivri Kapi (see fig. 5).[42] More important for understanding the structural chronology of the wall system are the postern gates in the lateral walls of the projecting towers, which open onto the terrace located behind the main outer wall.[43] This terrace was built against the west face of the inner wall and is recorded as being w. 16.4–21 m, with an arcaded wall to the west. This is the main outer wall and the parapet is supported on arcades (see below); the wall itself has a thickness between 0.6–2 m and rises 9 m above the outer terrace. The wall walk with parapet is w. 3.4 m, and rises 4.4 m above the inner terrace; there are interval towers located midway between the towers of the main inner curtain and, in some towers, posterns give access to the lower outer terrace. This is w. 20 m with a parapet overlooking the ditch.[44] The ditch is square in section, w. 20 m, with a maximum depth of 7 m near the Golden Gate, and side walls th. 1.6 m, with buttresses.[45]

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[42] *Cod. Theod.* 15.1.51; for the hypogeum see Deckers (1993). The site of the hypogeum before excavation is shown in fig. 5.

In total, the difference in height between the bottom of the ditch and the parapet of the inner wall is *ca.* 30 m. But the distance from the outer face of the main curtain to the outside edge of the ditch is even more impressive, at *ca.* 60 m.[46] Without accurate measurements based on excavation, it is difficult to be certain of the relevance of the apparent ratio of 1:2, but it seems likely that it was a factor in the overall design. The presence of the postern gates in the inner and outer towers does, however, allow greater certainty about the unity of the plan. Far from representing a system of fortifications which evolved over three decades and more, as has been suggested from a historical analysis of the epigraphic sources,[47] it is clear, from structural evidence, that the construction of the main inner wall came first.

The terrain varies considerably across the peninsula, from the high ground at the Edirne Kapı to the depression across the valley of the

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[43] Ahunbay and Ahunbay (2000) figs. 25, 31 shows the postern gate opening onto the inner terrace.

[44] The arrangement of a low parapet fronting the ditch compares with most examples of outer walls (*proteichismata*) known from Late Roman fortifications; see Smith and Crow (1998) 66–69 for a discussion of outer walls in the Balkans and the Roman east.

[45] The dimensions are derived from Van Millingen (1899) 51–55, see also Meyer-Platt and Schneider (1943) and Müller-Wiener (1977) 268–311.

[46] See the cross section and elevation published by van Millingen (1899) facing 106, 107; these form the basis for all subsequent studies, despite all the recent restoration work no excavated archaeological section through the wall and terraces has been undertaken.

[47] See Bardill (2004) 122–24; although this is not to ignore the very extensive evidence for later restorations, see the results of careful survey and excavations: Ahunbay and Ahunbay (2000).

Lykus. But if we can generalise from van Millingen's section,[48] it would appear that the ground level on the inside is lower than on the outside. This was the result of a terrace constructed against the outer face of the main inner wall. We may suggest that the construction sequence commenced with the building of the main inner wall, but more or less contemporary with it came the digging of the ditch 40 m to the west. The cross section of the ditch is approximately 140 m^2, and the terrace between the inner and outer walls can be estimated to have a cross section of 80–85 m^2; clearly the upcast from the ditch would have been more than sufficient to create the terrace fronted by the outer wall (see fig. 4). The postern gates in the towers of the inner curtain open at the level of the terrace, between the inner and outer walls, which demonstrates that the outer wall was always part of the original scheme, despite the apparent difference in construction technique between the two walls. To suggest that the outer wall was added at a significantly later date, as has been frequently inferred from the historical sources, presumes that these primary posterns originally opened above the original ground surface at a high level, which is both impractical and highly unlikely. The position and the chronology of the hypogeum close to the tower also make sense. It is likely to have been built after the construction of the inner wall when soil from the ditch was being heaped up against it, as part of the creation of the inner terrace. The building of the tomb could be a little later, but it certainly postdates the process of the creation of the Land Walls.

It is however salutary that, over a century after the publication of van Millingen's original study of the Land Walls, we have hardly advanced in our understanding; only as a result of the recent study of the curtain do we at last recognise that, like on other late antique walls, there were two levels of firing platform on the inner curtain, comparable to the main outer wall. In the first phase, evidence survives for a regular sequence of internal buttresses, set behind the merlons, located 2.5 m apart and projecting 0.8 m internally. This matches the similar arrangement of the outer wall.[49] Within the structure of the primary wall top, a number of flagstones with large rectangular sockets were discovered, which could be located in the primary embrasures. They provide valuable evidence for the use of torsion artillery (*ballistarii*) as part of the original scheme of defence.[50] It has further been suggested that this arrangement of a two-tier wall-top defence, matching that of the outer wall, was later replaced by a single row of substantial T-shaped battlements. Comparison with other Late Roman defences strongly suggests that this second scheme is very similar to other systems of embrasures and upper parapet walls. However, Professors Ahunbay and Ahunbay are certainly correct in drawing attention to the vulnerability of the primary scheme to earthquake damage.[51] It is quite possible it only survived until the massive earthquake of A.D. 447, which is known to have extensively damaged the Land Walls.[52]

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[48] The essential details are confirmed by the most recent study, which records the inner curtain as w. 4.85 m, rising to a maximum height of 12 m and with projecting towers located 50 m apart; the outer wall is located 16 m to the front of it: Ahunbay and Ahunbay (2000) 229, 238.

[49] The evidence for the phases of the inner curtain is described by Ahunbay and Ahunbay (2000) 235, figs. 21, 23, with a reconstruction fig. 24; for the outer wall, see (2000) 235–36, figs. 31, 32.

By way of comparison, fig. 6 shows a photograph of the walls of Amida (modern Diyarbekir), taken in 1907. This is the best-preserved example of a 6th c. fortress from late antique Mesopotamia. Although the city's defences underwent extensive medieval and later restorations, the essential elements date from the time of Anastasius and Justinian. In front of the main curtain wall and towers, remains of the outer wall, typical of late antique defences, are preserved.[53] In contrast, fig. 4 shows a photograph of an unrestored section of the Land Walls of Constantinople. All the main elements as outlined above are apparent. However, the comparison reveals the difference that is created by the Constantinopolitan outer wall and inner terrace. Despite numerous attempts to associate the design of the walls with the works of Hellenistic

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[50] Ahunbay and Ahunbay (2000) 236, fig. 23. These important discoveries contradict Foss's suggestion that the absence of inner loopholes necessitated building the outer wall (1986) 45.

[51] The evidence for the second phase is discussed in Ahunbay and Ahunbay (2000) 235, and fig. 21 shows phase one as a dark-grey stipple and the phase two T-shaped battlements (marked A-C) in outline. These later 'battlements' are substantial in size, w. 1.65 m and project internally from the outer face of the curtain by 2.2 m., and are comparable with similar features known from Actia Nicopolis, Silivri and elsewhere, see Crow (2002) 343–44, fig. 4; on these walls instead of a wide two-storey parapet, see the illustrations of the Silivri walls by Covel (1998), 48–50, figs. 11–12; a more detailed study of the walls of Silivri will form part of our forthcoming monograph on The Anastasian Wall. See also recent work on Late Roman wall tops in France, see Wood (2002), Foudrin (2002) and Darles, Badie and Malmary (2002), all three articles discuss the evidence for traverses in the merlons.

[52] See the recent critical discussion of the evidence for the earthquake of A.D. 447 in Bardill (2004) 123.

[53] See Gabriel (1940) and Crow (2007).

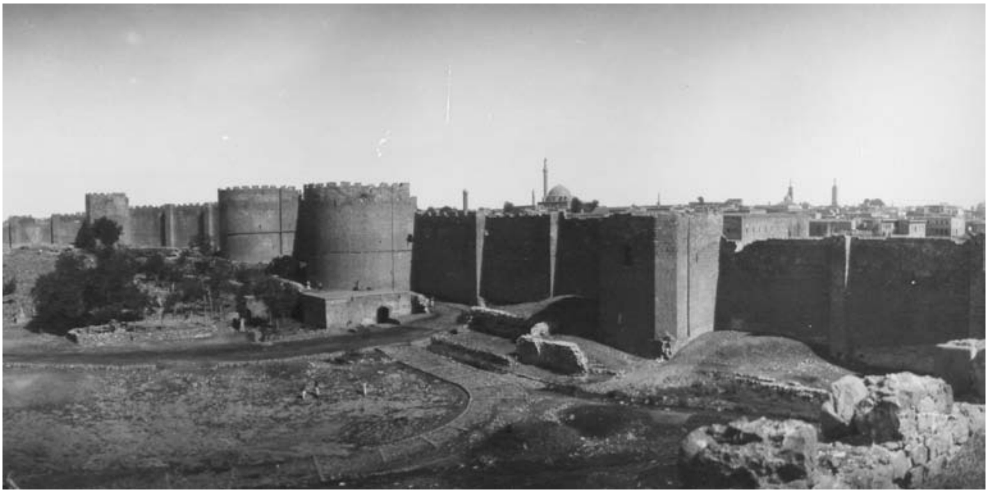

Fig. 6 The Mardin Gate, Amida (Diyarbekir), note the low outer wall surviving in front of the gate tower (Gertrude Bell Photographic Archive, Newcastle University, 1907).

writers, especially those of Philo of Byzantium,[54] it is clear that their construction was an entirely novel response to the requirements of the new capital. They represent not only the most massive fortification in the ancient world, but surely the most successful. In terms of the infrastructure of the city, whatever the actual costs, the benefits—with the exception of the sack of A.D. 1204—lasted for over a millennium.

Water Supply (fig. 7)

Within the city of Constantinople, the vestiges of the urban water supply are among the most impressive structures to be seen, including the aqueduct of Valens[55] and more than 150 covered cisterns and

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[54] See the cautious comments in Ahunbay and Ahunbay (2000) 237, n. 21; see also Crow (2001) 92, esp. n. 16; and note the reservations expressed by Spieser (1986) 365.

[55] Recent studies often prefer to describe the Bozdoğan Kemeri, the Turkish name for the long arched bridge between the Third and Fourth Hills, Müller-Wiener (1977), as the *so-called* aqueduct of Valens. Archaeological evidence, however, indicates that the structure does in fact date to 4th c. A.D. (see note 73) *contra* Mango (1990) 20; see the discussion of Valens' building programme in Lenski (2002) 278, 393–401, esp. 399.

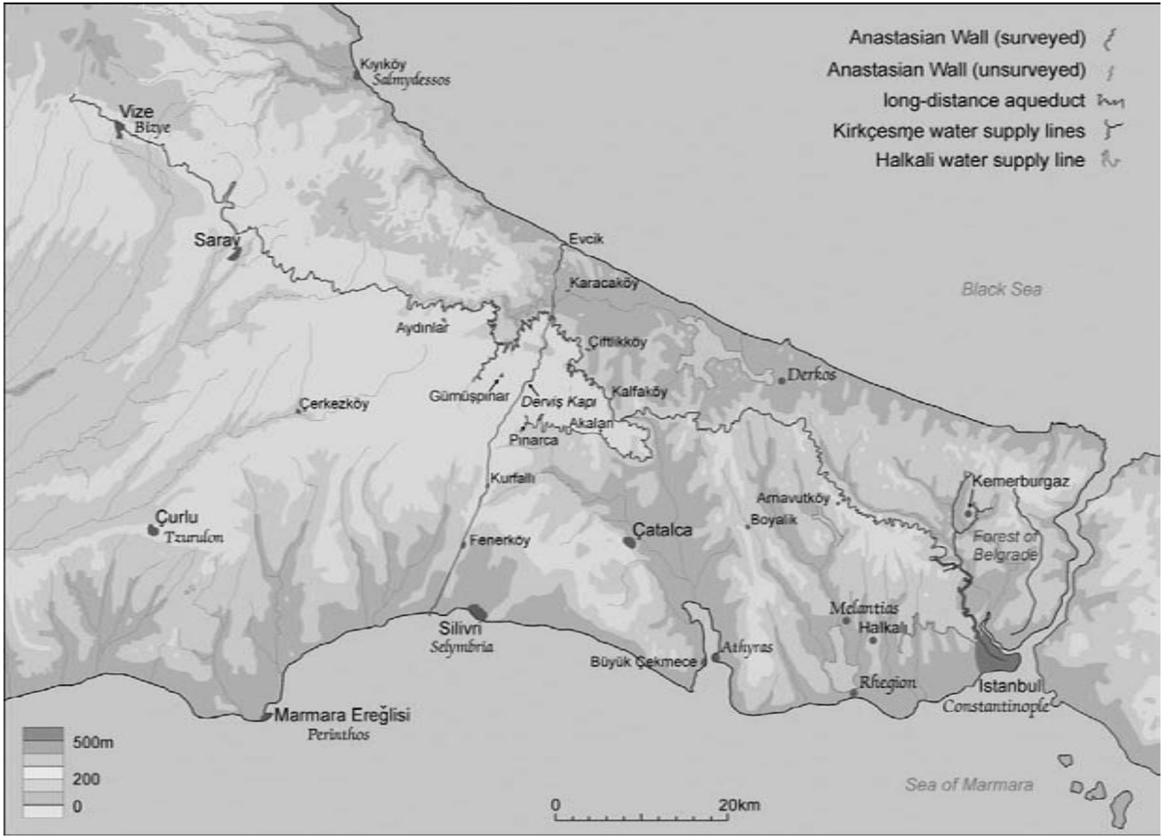

Fig. 7 Map of Thrace showing the lines of the Byzantine water supply systems and the Anastasian Wall. Note the first phase of the Long-Distance Water Supply is shown west of Gümüşpinar (Richard Bayliss).

reservoirs.[56] Recent research, however, has concentrated beyond the city's limits, and over the past decade fieldwork has finally revealed something of the complexity and scale of the aqueducts and water channels built between the 4th and 6th centuries. In the 6th c., several chroniclers refer to an aqueduct of Hadrian, a legacy from the former Greek colony of Byzantium. More reliable and informative are the accounts of the 4th c. orator Themistius: he praises Valens for inaugurating the city's aqueduct in A.D. 373 and also Constantius II, who in A.D. 345 began the construction of his eponymous baths, located in the Tenth Region of the city, between the Church of the Holy Apostles and the west end of the Aqueduct of Valens. Moreover, the same account records that in the same year the emperor initiated the search for springs and more abundant water: clearly the two actions can be associated.[57] Themistius stresses the importance of the new water provision by commenting that, whatever Constantine and Constantius II had given the city by embellishing it with statues and public buildings, it remained nothing more than a sketch that was 'girdled by gold but dying of thirst'.[58] As with so many other aspects of the expansion of Constantinople during the 4th and early 5th centuries, the process of development took time. It is, however, worth noting that the new aqueduct system was initiated only 15 years after Constantine's inauguration and may have always been part of the plans for the new city.

Written accounts are much more concerned with the creation of the water supply system in the 4th c. than with its maintenance or extension; from Theodosius I onwards, texts concerning the aqueducts become sporadic and limited. A law of A.D. 396 mentions an aqueduct *Theodosiacus*.[59] Although it is not clear which part of the system this refers to, it is likely to refer to the extension and re-building of the long-distance line in Thrace. In the 6th c., Hesychius reported that the source of this aqueduct was at Bizye (modern Vize), at a distance much further than the 1000 *stades* given by Themistius.[60] As we shall see, this was an

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An air photo taken in 1910 shows how the line of the aqueduct dominates the city, Çelik (1986) fig. 12.

[56] Mango (1995) provides an authoritative summary of the literary and topographical evidence; the results of recent fieldwork are summarised in Romey (2003), and Crow and Bayliss (2005).

[57] Themistius *Or.* IV 58a.

[58] Themistius *Or.* XI 151a; Dagron (1984) 90; Mango (1995) 13.

[59] *Cod Theod.* 6.4.29–30.

[60] Mango (1995) 13.

accurate assessment of the final extent of the system. Although 5th and 6th c. sources are less concerned with activities outside the city, there are increasing references in either contemporary or later chronicles to a developing pattern of open-air and closed cisterns.[61] In *ca.* A.D. 500, three great open-air cisterns were constructed in the west part of the city enclosed by the new Theodosian Land Walls, together with an increasing number of large closed cisterns, including the Basilica Cistern (Yerebatan Saray) and the Binbirdirek ('1001 columns'), built by the time of Justinian. A major distinction between the two imperial capitals of Rome and Constantinople was the extensive use of water storage within the walls of the latter city. Whilst Rome, from Augustus onwards, relied on the frontier armies for its security, Constantinople acquired increasingly complex systems of fortifications. Thus the large number of cisterns and reservoirs was necessitated partly by the needs for security but also by the different character of the water sources available to the city.[62] Constantinople lies at the south-eastern extremity of the Thracian peninsula, and local geology dictated that the spring sources with the best hydraulic potential were located at a considerable distance to the west of the city, in the metamorphic range of the İstranca massif.

Until recently, very little systematic fieldwork had been carried out on the late antique water-supply system beyond the city walls. Significantly, the important article by the Turkish archaeologist, Feridun Dirimtekin, published in *Cahiers Archéologiques*, does not figure in any of the major studies on Roman aqueducts,[63] perhaps a reflection of the divide between classical and late antique/Byzantine studies. Our own work on the Anastasian Wall and the water supply system commenced in 1994, but Professor Kâzim Çeçen had already begun a detailed reconnaissance of the water channels and aqueducts to the west of Istanbul to complement his important studies of the water supply of the Ottoman city.[64] This research provided the first coherent interpretation of the Thracian water supply for Constantinople. His study was provocatively, but correctly, entitled *The Longest Roman Water Supply Line*. He estimated that the system, from Istanbul to Vize, where he had traced channels, was 242 km in length. Subsequent research has suggested it is 336 km long, nearly three times longer than the known length of any known Roman water supply. The water provision of Constantinople can be divided into two principal water supply lines.

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[61] Earlier studies are summarised in Mango (1995) 14–17; the dates of many of the open and closed cisterns have been recently reassessed in Bardill (2004).

[62] See Crow, Bayliss, Bono (2001).

[63] Dirimtekin (1959); for recent aqueduct studies, see Hodge (1992); (2000).

[64] Crow and Ricci (1997); Çeçen (1996a).

The Long-Distance Channel

At its maximum extent, this system drew water from over 120 km away in the region of Bizye (modern Vize), and in total, between the furthest source and the city, its sinuous channel runs for more than 336 km. This was not the first aqueduct constructed in the 4th c. and completed under Valens, but an extension dating to the early 5th c. The first channel supplying the Aqueduct of Valens in the city began at the major springs in the valley of the Karamandere, near the village of Danamandıra, a distance which approximately corresponds with Themistius' claim of 1000 *stades* (185 km).[65] We now also know of a second major source and channel from this primary phase of the system, beginning at the springs at Pınarca. The western extension to Vize commences at the Ballıgerme aqueduct. Its most distant source is located on the outskirts of the village of Pazarlı, north-west of Vize, while another major spring is located at the source of the Ergene river, 6 km east of the town. It is now clear that there was not a single line of water channels, but a more complex dendritic pattern of main channels and tributaries throughout its length, with at least two major periods of development; closer in practice to the system of multiple aqueducts that developed around Rome.

The main surviving elements of the system as a whole are the bridges, built to carry the aqueduct channel across the steep-sided valleys and through the forested hill country of the Istranca range. Around 60 aqueduct bridges have been identified within the system as a whole, and 19 of these are more or less intact with high, massive stone piers and great vaulted arches.[66] The channel was constructed by 'cut and cover' techniques and was roofed with a rough stone vault. In many places the hydraulic lime-mortar lining of the sides of the channel survives, often with later accretions of distinctive travertine or sinter deposits that have accumulated with the passage of water. The vaults and the channel walls are constructed of metamorphic or limestone blocks, with some distinctive variation in construction technique depending on period, locality and scale of the channel. Distinct widths of channels have been noted in different parts of the system. The primary channels from around Danamandarı and Pınarca are narrow with a width of 0.6 m and a maximum height of 1.6 m, but to the east of the Ballıgerme aqueduct, in the same region where the two systems converge, the Vize line flowed in a much broader channel 1.6 m wide and nearly 2 m in height.

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[65] Mango (1990) 42, n. 33. We calculate the length of this channel at 215 km.

[66] For illustrations and the location of the bridges, see Cecen (1996a); Crow and Ricci (1997); Romey (2003); and Crow and Bayliss (2005).

Where the two lines run parallel, the broad channel is located over 6 m below the narrow channel above. With this new channel, a new set of aqueduct bridges were built, including the great bridges at Kurşunlugerme and Büyükgerme. In some places, the earlier bridges continued in use, but elsewhere they were abandoned. The two lines gradually converge in height by the time they reach the aqueduct at Büyükgereme, near Ciftlikköy, but despite extensive exploration, no evidence has been found of a junction between the channels, and it remains likely that both reached the city as individual, unconnected channels at more or less the same height. Despite the clear differences in tunnel size which can be seen in the area between the villages of Gümüspinar and Ciftlikköy, further west towards Vize, the channel is mostly observed at a narrow gauge. Towards Istanbul, evidence for the broad channel is also absent.

The last third of the channel is rarely evident in the open ground, but covered by the extending modern city of Istanbul. On its final approach to the city, this system followed the western edge of the Alibey Valley, although its remains are now lost beneath the damned waters of the Alibey Baraj. The channel(s) would have passed the line of the later Theodosian Walls close to where the Edirne Kapı was later built. At this point the elevation of the channels would have been 63–64 m, which is confirmed by the 971 m long aqueduct bridge, the Bozdoğan kemeri, or Aqueduct of Valens.

Consequently, much of the line of the channel, proposed first by Çeçen, and subsequently by Bayliss and Crow, is hypothetical, created by joining the positions of known bridges and sections of exposed conduit. Implicit in the projected line are a number of tunnels, up to 1.5 km in length, although the physical evidence for these is very limited. But the sinuous nature of the supply line, as it followed the four major valleys in the Istranca hills between Vize and the city, is recalled in Themistius' oration to Valens when he colourfully describes the Thracian nymphs 'who undeterred by rocks, mountains or ravines, skirted these obstacles, burrowed under them or flew through the air'. The physical undertaking of this project was huge, and today we can only marvel at the surveying skills which made it possible to lead water across hundreds of kilometres of difficult wooded terrain, into the city of Constantinople. Far from being the work of an empire in decline, this possibly ranks as the greatest engineering achievement in the ancient world, comparable to the Land Walls of Theodosius and to Justinian's Great Church of Hagia Sophia.

The Forest of Belgrade and Halkalı

Other water sources are located much closer to the city and it could, therefore, reasonably be assumed that they were the first to be exploited by the colony of Byzantium. These springs were extensively re-developed by the Ottomans from the late 15th c. onwards, so it is often difficult to define the surviving Roman and Byzantine features of the system. Soon after the Ottoman conquest of Constantinople in 1453, Mehmet II ordered the restoration of the Byzantine water supply channels, most probably those to the north-west of the city, in the Forest of Belgrade. Following the establishment of this first supply line, a more extensive network, the Kırkçesme ('Forty Springs') system, was developed, maintained and expanded throughout the Ottoman period, with a multitude of lines drawing water from such different sources as springs, streams or substantial dams. Ottoman sources refer to earlier structures, and traces of structurally earlier late antique and Byzantine work have been noted at a number of places in the Belgrade forest.[67]

The closest aquiferous zone to the city is located some 15 km to the west, in the region of Halkalı near modern Kücükcekmece. This area was also extensively exploited for its water resources in the Ottoman period, and several scholars have assumed that it was from here that the first aqueduct channel for the city ran. The elevation of the principal springs is significant because, unlike the Cebeciköy and Kırkceşme sources, they were located high enough (55–65 m at the Land Walls) to provide for the whole area of the city. Dalman, Eyice, Çeçen and, most recently, Mango, have argued that the surviving aqueduct bridge known as the Maz'ulkemer is most likely the last surviving element of the Roman and Byzantine system in this area. However, the Halkalı springs can only supply a relatively limited amount of water; in 1922 its output volume was only half of that of the Kırkceşme springs. Furthermore, there is no direct evidence for Roman or late antique interventions to this line. Indeed, it is possible that Constantius' prospectors disregarded the source as insufficient for the ambitions of the capital.[68]

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[67] Crow and Bayliss (2005); Çeçen (1996b) 169–73.

Water Distribution within the City

One of the major problems affecting the water provision for Constantine's new city was not simply the volume of water available, but also the problems created by a gravity-based water-supply system. Quite simply, many of the new parts of the city were at a higher elevation than the core of old Byzantium at the east end of the peninsula, and any pre-existing water supply could not be expected to be able to effectively provide running water for fountains and baths. It is for this reason that earlier studies needed to invoke at least the Halkalı springs. The main Ottoman channel, the Cebeciköy/Kırkceşme line, entering the city at a height of 35 m, was adequate for the requirements of the early Greek and Roman settlement.[69] Only as the city expanded up and beyond the Second Hill, in the early 4th c., was a higher water provision required.

Having established the two main water main supplies beyond the city walls, it is possible to develop the following model to investigate the water-distribution system inside the city based on the following elements (see fig. 1):

- Water from the Belgrade Forest (Kırkceşme) supply line could only have provided water to cisterns and reservoirs in the city lying at an elevation below 35 m.
- Water from the long-distance supply line could only have provided water to cisterns and reservoirs in the city lying at an elevation below 64 m.

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[68] Mango (1995) 10; see now Crow and Bayliss (2004).

[69] Çeçen (1996b) 143–44.

The lines of the channels within the city are not known,[70] but in order to investigate this hypothesis, Bayliss established a computer-based model which reconstructs the course of the two water channels into the city: one from a point north of Edirne Kapı at an elevation of 64 m, and the other from just north of Eğrı Kapı at an elevation of 35 m, with an assumed regular gradient of 1 m per km (fig. 1). Plotted onto a topographical map of the city, it becomes apparent that there is a correlation between the two projected tracks and the location of many of the known cisterns. The projected course for the upper channel passes close by the Aetios and Aspar reservoirs, maintaining the correct elevation to cross the Valens Aqueduct, which it must have done before turning south towards the Forum Tauri and proceeding along the line of the Mese and finally terminating at the Binbirdirek Cistern, on the promontory of the Second Hill. Other clusters of cisterns lying away from this line, but situated above 35 m, must also have been supplied by a channel of this altitude.[71]

The line of the water channel from Çebecikoy and the Forest of Belgrade was similarly projected through the city from a height of 35 m at the Land Walls. Once again, Bayliss has been able to establish a close correlation between the path of the channel and the positions of known cisterns. The projected channel hugs the steep hillsides above the quarters near the Golden Horn, a route that ultimately would have taken it right to the heart of the old city. A branch in the channel between the Fourth and Third Hills, as in the Ottoman system, could have then passed along the south side of the Third and Second Hills to the area of the Imperial Palace. Along its route, the proximity of Ottoman fountains to many surviving Byzantine cisterns underlines the correlation between the two systems. Indeed, the Byzantine line can reasonably be assumed to have entered the city in the vicinity of the surviving Ottoman Kırkceşme distribution centre, situated just outside the Eğrı Kapı at the north end of the Land Walls. Significantly, there are no substantial cisterns until the channel crosses the assumed line of the Constantinian walls. Rounding the north side of the Fourth Hill it then follows the contour immediately behind the large Unkapanı cistern, situated on the west flank of the Atatürk Bülüvari and below the Pantocrator monastery. After running along the north side of the Third and Second Hills, the projected line of the channel passes close to the Basilica Cistern (Yerebatansaray), which is situated sufficiently deep beneath the modern ground surface to have been fed by it. From here, a branch possibly turned to the north-east to run along the flank of the First Hill, probably supplying the cisterns known in and around the Topkapı Palace, and then onto cisterns in the vicinity of the Imperial Palace and Sphendone of the Hippodrome, all apparently situated at an appropriate elevation.

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[70] See the illustration of stone water pipes in Müller-Wiener (1977) figs. 303, 305.

[71] A full concordance of known and recorded cisterns forms part of the new monograph on the water supply of Constantinople (Crow, Bardill, Bayliss 2008).

This summary has presented some of the archaeological and topographical evidence for the two water supply lines of different heights and origins. The lower line—originating to the north of the city—supplied the area of the Imperial Palace and most probably also the Basilica Cistern. The upper line—originating deep within Thrace—supplied the baths of Constantius II and the Cistern of Modestus (and Arcadianus) before crossing the Aqueduct of Valens and terminating at a *castellum divisorium*, situated near to or south of the eastern end of the aqueduct. The line was later extended to supply the grand nymphaeum on the Forum Tauri, while a substantial expansion of the entire system to springs near Vize in the 5th c. was probably necessary to serve the three massive intra-mural reservoirs located in the new area of the city between the Constantinian and Theodosian Land Walls, as well as the many new cisterns constructed in the 5th and 6th centuries.

Textual evidence for the existence of two supply lines comes from the following passage in Malalas, where he refers to restorations undertaken by Justinian in A.D. 528: 'He built the central hall of the Basilica cistern, intending to bring the water of Hadrian's aqueduct into it. He also reconstructed the city's aqueduct'.[72] A clear distinction is drawn between the aqueduct built by Hadrian and the 'city's aqueduct', and since we can identify the Basilica Cistern, we can therefore associate the Hadrianic Aqueduct with the lower level supply line. From this we can infer that that what Malalas describes as the 'city's aqueduct' was the higher line which entered at a height of *ca.* 64 m and flowed across the great aqueduct bridge of the Bozdoğan Kemeri. The date of this structure has been long debated, since in its current state it reveals numerous phases of repairs and restoration.[73] There is, however, independent and limited, but valuable, archaeological evidence[74] suggesting a 4th c. date for the structure. With a maximum height of 29.1 m and length of 971 m, it is certainly the longest aqueduct bridge (as distinct from arcades) in the Roman world.

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[72] Malalas 436–6; Jeffreys et al. (1986) 252.

Such a complex system required continual maintenance.[75] *The Secret History* records disrepair to the aqueduct and a water shortage in the time of Justinian. Characteristically, Procopius claims that: 'it was not the desire to save money but the set purpose of destroying his fellowmen that led him to neglect the re-building of the aqueduct'.[76] However, the recent discovery of an inscription questions this claim: it records repair work by a certain Longinus, ex-consul and prefect, on a small aqueduct bridge at the valley of Elkafdere, near Belgrat Köy, where the two long-distance channels run parallel.[77] The only prefect of the city with this name is recorded under Justinian, and the form of the building work is quite different from the main bridges constructed during the major building phases in the 4th and 5th centuries. For instance, at the springing of the vault of the arch, a distinctive form of moulding is used, where the string courses are angled towards the top rather than towards the bottom as is usual. At Elkafdere, this feature is seen at the springing of the vault of the archway. Elsewhere, the same element is found at a number of major bridges where there is a very substantial re-building, either a complete re-construction or an extensive cladding of the structure of the earlier bridge. This sequence of re-building was first observed by Dirimtekin at Talas,[78] and it is also known from Cevizlikkale, Lukadere, Leylekkale and Ortabel, all four of which have distinctive buttresses and blockwork construction. A further use of the distinctive string course is also found at the raised embankment east of Büyükgerme. By analogy with the dated example from Elkafdere, we can suggest that this work may be attributed to the period of Justinian. They were possibly the result of very specific seismic damage, since all but one of the renewed bridges are located in a 10 km length west of the villages of Belgrat and Ciftlikköy. The work of repair was not noted in Procopius' *De Aedificiis*.

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[73] Mango (1995) 12; Striker and Kuban (1997) fol. 31. provides a detailed elevation of piers 77–78.

[74] Harrison (1966) pl. 61.1 notes 4th c. A.D. pottery from the lowest levels of sounding next to pier 45, 4.5 m below the modern ground surface; note that Ward-Perkins (1958), in his study of Early Byzantine construction, accepted the date of A.D. 368 for the Aqueduct of Valens, p. 65, pl. 17 A. Striker and Kuban (1997) observe that there is little difference in ground surface between Late Roman baths at Kalenderhane and the adjacent aqueduct piers; a *chrismon* decorated key-stone is known from the south elevation, Crow and Bayliss (2005).

[75] A law of Leo required new consuls to provide 100 pounds of gold for the maintenance of the aqueduct instead of the 'vile practice of scattering the money among the populace' *Cod. Just.* 13.3.2.

[76] Procop. *HA* 26.23.

[77] Longinus is known to have been prefect from A.D. 537–*ca.* A.D. 542, *PLRE* III *sv* Longinus 2; see also Feissel (2000).

[78] Dirimtekin (1959) 230–32.

Conclusion

Each of the three examples discussed in this paper reveals something of the uniqueness of the late antique city of Constantinople. Recent research has shown the scale and complexity of the water supply system, which in less than a century became as long as the eleven aqueducts of Rome. Precise figures are lacking. However, if we combine the length of 242 km which Çeçen suggested, with the original 4th c. line of *ca.* 185 km, plus the rebuilt and extended aqueducts of the Belgrade Forest, the total figure approaches the combined length of 502 km estimated for imperial Rome.[79] Within the city, the aqueduct bridge of the Bozdoğan Kemeri provides an iconic statement of Late Roman water engineering,[80] and the extensive system of water storage in closed cisterns and open reservoirs is unmatched elsewhere. Large cisterns are rare in Rome itself, although other cities, notably Carthage and Alexandria, used them extensively, for storage and distribution.[81] They are a distinctive feature of Constantinople, where there is clear evidence that the nature of the rainfall and discharge from the springs influenced the decision to build large cisterns; but instead of using the normal barrel vaults and concrete piers to support the vast roof span, they were monumentalised by the use of columns of capitals.[82] Resources and security became intertwined themes in the city's history. The size and location of the open reservoirs within the newly-constructed Theodosian Walls reminds us that in A.D. 378, less than 50 years after Constantine's foundation of the city, and only five years after Valens welcomed the new waters into the city, it was directly threatened by the Goths. But Constantinople did not just match Rome in scale: there is also evidence for innovation; not only in the use of cisterns and reservoirs, but also in the provision of water towers to balance water flow, known from the open cistern of Aspar in the city, and from the Fildami, near the palace at Hebdomen.[83]

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[79] Hodge (2000) 65, table 3; Blackman and Hodge (2001) 2, table 2; 153–54, fig. 6.

[80] The Valens Aqueduct (Bozdoğan Kemeri) passing between the Third and Fourth Hills is certainly the longest known Roman aqueduct bridge at 973 m, matched only by the arcade/bridge in Segovia which is 723 m long and 28 m. high, Hodge (2000) 75, fig. 6.

[81] In the later 1st c. B.C., Strabo describes how 'almost every house in Rome had cisterns and service pipes' (*Geographica*, 5.3.8) although these are not reflected in the urban archaeology, see now Rome and Italy: Blake and Bishop (1973) 276–78, De Kleijn (2001) esp. 84–97; Taylor (2000) 64–66; Sear (2004) 165–66; for Carthage, see Wilson (1998) esp. 71–77.

To achieve the infrastructure discussed here required massive investments of time, manpower and resources. It is easy to dismiss the modern estimates of time for ancient projects as futile musings,[84] but it is important to recognise that the main period of building of the aqueducts, cisterns, terraces and walls was between *ca.* A.D. 350 and 450. To take one example from these undertakings, just to excavate the ditch for the Theodosian Wall would have involved digging out 910,000 m^3 of soil and clay, and that does not even begin to estimate the amount of stone and brick required at this time for the walls and other projects. The ditch alone, based on comparisons with Romania in the 1930s, would have taken over 600,000 days of labour.[85] But this was just one component in the creation of the great city during the 5th c. The laying out of the colonnaded streets, piazzas and terraces, the excavation of the massive open reservoirs, the construction of harbours, defensive walls and water supply were all completed within less than 150 years from the death of Constantine to the time of Anastasius.[86]

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[82] Hodge (2000) 93–94; he provides figures to incorrectly show that the Yerebatan Saray is ten-times the size of the largest Carthaginian cistern, the Bordj Djedid! Note he confuses the names of the Binbirdirek (1001 columns) and the Yerebatan (Basilica) cisterns, n. 30.

[83] For the date of the cisterns, see Bardill (2003) 39, 61. The dating of these towers is uncertain, since they are structurally later than the main structure of the cistern walls. They are different from the circular taproom known from the Dar Saniat cistern at Carthage, Wilson (1998) 71.

[84] See the discussion of the costs and financing of Roman aqueduct building by Leveau in Blackman and Hodge (2001) 85–101, esp. 99.

[85] Squatriti (2002) 41; that is approximately 1000 men working for two years, taking in to consideration holy days and poor winter weather.

[86] See the fictionalised account of the impact of the building of the Aurelianic Walls of Rome, quoted by Christie (2001).

The opening quotation concerning "great cities" reminds us that "bigness implies complexity". Constantinople, by the 5th c., had become both 'great' and 'big'. The citation is taken from Peter Hall's study of *Cities in Civilisation*. Most of his examples and discussion are drawn form the early modern or modern western world. In the part entitled "The Establishment of Urban Order", Hall contrasts ancient Rome, and especially its water supply, with the developing cities of London and Paris in the 19th c., as they sought to accommodate increasing urban populations and create new infrastructure. In late antique Constantinople we can recognise developments of a similar scale and complexity. The Byzantine capital was able to sustain a large part of this infrastructure throughout the Early Middle Ages. In the ancient world, ambition and innovation did not end with the Antonine Golden Age;[87] in the East, they were maintained, albeit with a new ideology, and in Greek rather than Latin. John Ward-Perkins in his study of the building materials and techniques of the late antique city wrote:

> Where Constantinople differed from all its predecessors was in the unique and unqualified success that attended the new enterprise. Out of the dust and confusion of the third and early fourth centuries there emerged a new pattern, a pattern which was to influence every aspect of human thought and activity, and which inevitably found expression in the architecture of the new age.[88]

These observations can be extended beyond the architectural achievements of Constantinople. Even if its practices of urban space and order do not fully match those classical ideals of the ancient world,[89] it still became a civilization unique in Early Medieval Christendom; a centre of technological and artistic achievement recognised by the Arab-Islamic world,[90] and as Michael Lewis' paper shows, was recognised as a scientific and technological equal by the distant Chinese empire.

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[87] See the important discussion by Cameron (2003) about western attitudes and prejudices to Byzantine culture and history. A recent study of hydraulic technology in medieval Europe is limited to a very western perspective. See, however, the evidence for continuity in ancient water technology in Italy; Magnusson and Squatriti (2000).

[88] Ward-Perkins (1958) 102.

[89] See the instructive comparisons with 'great' Islamic cities in Northedge (2005).

[90] El Cheikh (2004) 59–60.

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WATER TECHNOLOGY AT GORTYN IN THE 4TH–7TH C. A.D.: TRANSPORT, STORAGE AND DISTRIBUTION

Elisabetta Giorgi

Abstract

The technology used to secure supplies of urban drinking water can reveal much about the management of the natural landscape. Gortyn in Crete provides an exceptional case study, for the 4th–7th centuries A.D., due to the almost complete preservation of the city's water system; this can be deduced from its spring-fed capture points, through transportation and storage structures, right up to its distribution outlets to the citizens. These fortunate circumstances allow us to analyse an evolving distribution system, and to study related changes in water use by the inhabitants of this Mediterranean provincial capital.

Introduction

Hydraulic structures connected with the transport and distribution of drinking water are certainly amongst the most important features of late antique cities. Both literary sources and archaeological remains testify to the commitment, of the imperial administration, local authorities and city communities, to building and maintaining this infrastructure, which was of fundamental importance for the quality of urban life. The hydraulic system of Gortyn (Crete) is an important example because, under the olive-groves that cover the site, is preserved a complete system of aqueducts, pipes and cistern-fountains, of many phases, dating from Hellenistic times to the 7th c. The high level of preservation allows us to study closely the technical aspects of structures connected with the catchment, transportation, maintenance and distribution of drinking water, in an important city of the late antique Mediterranean.[1]

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[1] This paper forms part of my doctoral research at the University of Siena. My research began in 2001, as a collaboration between the Department of Archaeology and Art History of the University of Siena and the Italian School of Archaeology at

L. Lavan, E. Zanini, and A. Sarantis (edd.) *Technology in Transition A.D. 300–650*
(Late Antique Archaeology 4 – 2006) (Leiden 2007), pp. 287–320

Geographical and Historical Context

Gortyn is situated on the northern edge of the Plain of Messarà, close to the foothills of Monte Ida. The archaeological site includes, to the north, two low hills (the acropolis and Pervolopetra) which are separated by a narrow gorge. Through this gap flows the Mitropolianòs river, which then spreads out widely to the south-east into an alluvial fan created by the river itself, and then into the Ieropotamòs hydrogeological system (fig. 1).[2] The earliest human settlements, located on the rising ground to the north of the site, date to the Early Geometric period. But the city developed only from the Archaic period. Of the topography of the Greek town, the following elements are known: the acropolis, rising up on the hillside west of the river; the agora, with its odeion, where the famous 'Law code of Gortyn' is still kept; and finally, on the south-east side, perhaps on the very edge of the city, the Temple of Apollo Pythios.

When the city became the provincial capital of Crete and Cyrenaica, it expanded to the South-East. This is clear from the position of some important monuments: a theatre connected with the Temple of Apollo, a bath complex and gymnasium (converted later into a praetorium), the Baths of Megali Porta, the large theatre and the amphitheatre, where the medieval and modern village of Hagii Deka was later established. The urban plan of the city of the 6th–7th c. is little known; but it seems to cover a large portion of its early imperial predecessor. Some Christian basilicas—St. Titus, Mavropapa and Mitropolis—date from this phase, as does a domestic area of 6th and 7th c. date, around the so-called 'praetorium' and the Temple of Apollo Pythios.[3]

Gortyn's well-preserved aqueduct is composed of easily recognisable components: from those associated with water capture, to transport, storage and distribution. For this reason, it presents a rare, perhaps unique occasion to study the continuity of Greco-Roman hydraulic technology in a city of the 6th–7th c. A.D. However, until now, the water system has never been the subject of detailed archaeological investigation, except for a few limited excavations that were undertaken in order to date it.[4] This paper presents data collected during a topographical

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Athens, to manage archaeological research in the so-called Early Byzantine quarter at Gortyn. For preliminary remarks, see Zanini and Giorgi (2002) and (2003).

[2] For geomorphology, see Arnoldus Huyzendveld (forthcoming).

[3] Di Vita (1984) and (2000).

[4] Di Vita (1984); Belli Pasqua and La Torre (1994–95).

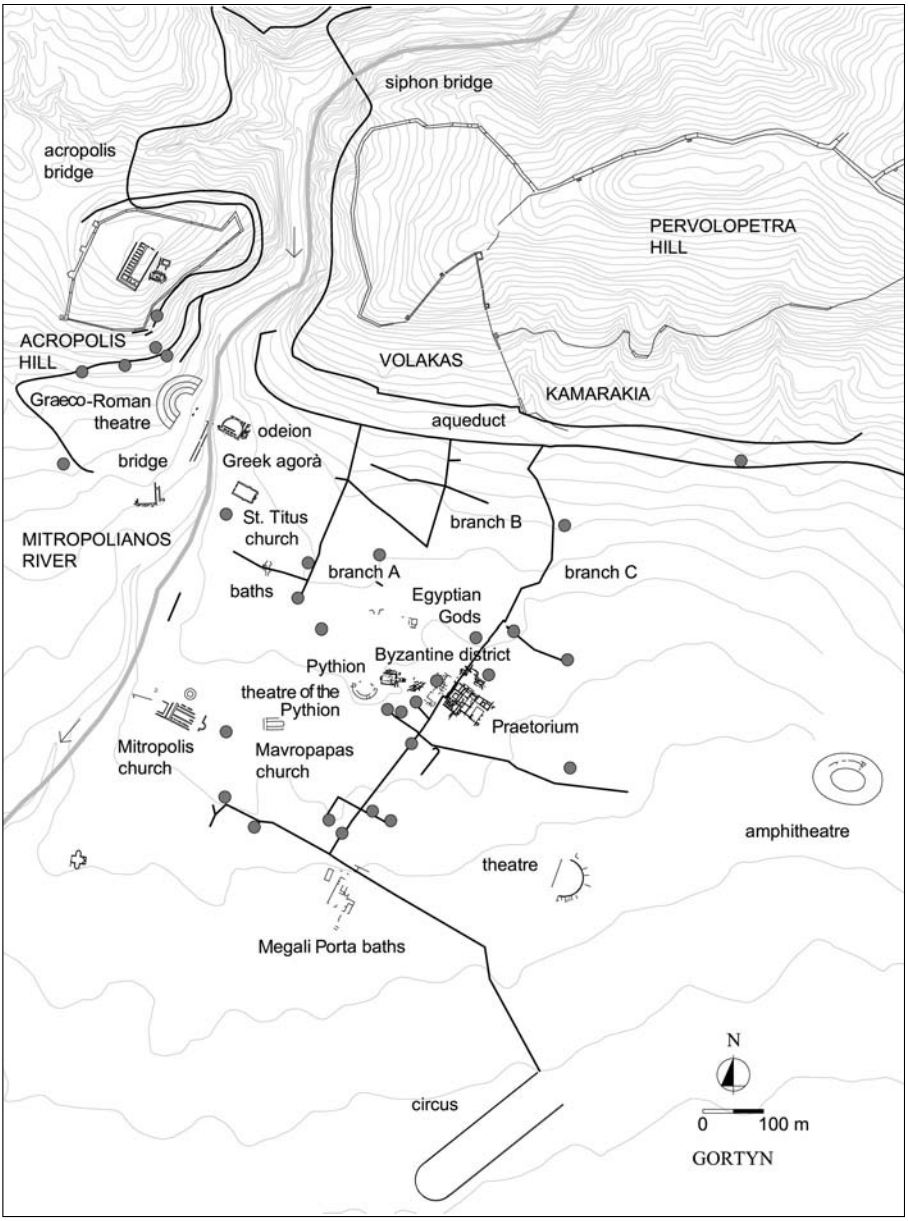

Fig. 1 Plan of Gortyn, showing aqueduct system (grey dots indicate early Byzantine cistern-fountains).

survey of Gortyn and adjacent areas,[5] which was undertaken in order to document all available archaeological evidence, and covered an area from the city centre towards the foothills of Mount Ida. The survey was carried out using a Global Positioning System, in order to position all elements on a digital cartographic base, ready to be managed by a Geographical Information System.

The study of hydraulic archaeology in the Early Roman period has been a multidisciplinary field for a long time.[6] In contrast, research into this topic for the late antique world is still in a preliminary phase. Pioneering works of scholarship have been based on the simple description of aqueducts and cisterns; but these are now frequently being replaced by studies that involve both the comparison of different types of sources, and new methodological approaches, which place archaeological evidence in technological, urban, geomorphological, environmental, historical and cultural contexts.[7] These approaches stress that aqueducts provide an important indicator of many aspects of urban life.[8] Water technology can provide many useful insights into the development of urban space and the transformation of housing, because of the close relationship between waterworks and the urban fabric.

Thus, it seems necessary to go beyond a simple technological approach, and look at the water system from wider perspectives, considering patterns of urban life as well as the structural context of infrastructure; this means considering people, who are the reason for the existence of such an infrastructure and who, through it, organised their life and work. The construction of waterworks to exploit a territory's water resources, and to organise water transport and distribution, represents an important element of continuity in urban life. In a diachronic perspective, water technology can provide a strong indicator of how cities changed during the 4th–7th centuries.

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[5] The survey has been undertaken with the permission of the Greek authorities.

[6] See, with bibliography, Hodge (1991) 163–73, and (1992).

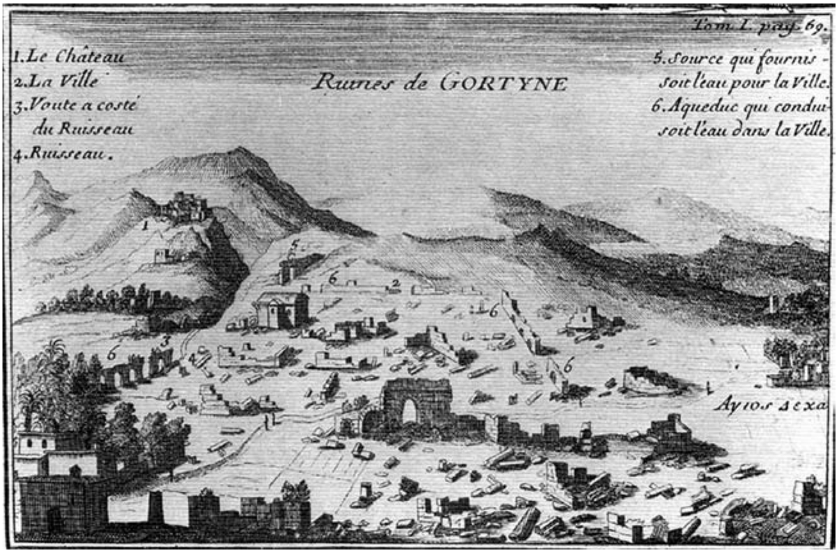
[7] Amit, Patrich and Hirschfeld (2000); Crow and Bayliss (2000) and (2005); Crow, Bayliss and Bono (2000) and (2001); see also on-line http://longwalls.ncl.ac.uk/Water/Constantinople.html; Dark (2004); Coates-Stephens (1998), (2003) and (2004); Wilson (1999); Winogradov (2002).

[8] Hodge (1991) 167.

The Sources and State of Research

The ruins of Gortyn's aqueduct have always been one of the most visible features of the site. They have, in fact, always been mentioned first in literary and iconographical descriptions since the Renaissance, when the city was visited by a number of early explorers. In the early 15th c., Cristoforo Buondelmonti provided a poetic description of the aqueduct's ruins.[9] These same remains must have been easily recognisable in A.D. 1717, when J. Pitton de Tournefort portrayed the city, in a detailed engraving, as being crossed by the water system (fig. 2).[10] This level of high visibility seems to have lasted until the first half of the 19th c.[11]

In the first years of the 20th c., Antonio Taramelli[12] directed an Italian Mission to Crete, the report of which constitutes the first 'scientific' description of the aqueduct. This report contains many precious details and technical observations, which permit a reliable reconstruction of


Tom. I. pag. 69.
1. Le Château
2. La Ville
3. Voute a costé du Ruisseau
4. Ruisseau.
Ruines de GORTYNE
5. Source qui fournis-soit l'eau pour la Ville.
6. Aqueduc qui condui-soit l'eau dans la Ville.
1
2
3
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Αγιος Δεκα

Fig. 2 Engraving of 1717 of J. Pitton de Tournefort, showing Gortyn being cross by a water system.

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[9] Buondelmonti (1420) 173–78: "*aque conductus descendens totam deinde rigabat vallem*".
[10] Tournefort (1717) I, 69.
[11] Pococke (1743–45); Spratt (1865); cfr. Masturzo and Tarditi (1994–95) 237–38.
[12] Taramelli (1902) 118–40.

parts of the system that have now been lost. This work became the starting point for a number of studies,[13] especially those of Francesco La Torre.[14] He was the first scholar to locate exactly the parts of the aqueduct closest to the city, and to map them accurately. The works of Mario Pagano,[15] only partially published, represent the first attempt at an overall interpretation of the urban aqueduct, which took into consideration its various chronological phases.

The Water System of Gortyn: A Short History

It is possible that from the Hellenistic period, the city had some kind of catchment system to carry water into the town. But it was only during the Roman period (the 2nd c. A.D.) that this was properly organised, with the construction of an aqueduct. The principal features of the Roman waterworks also seem to have survived, with restorations, during the late antique period. Since the Hellenistic and Roman phases of the aqueduct are not the focus of this article, they will here be described only in outline.

The Hellenistic Period

Our knowledge of the city's hydraulic system in the Hellenistic period is fragmentary. Archaeological excavations have been carried out in some portions of the city, but these have only revealed short segments of underground conduits (earthenware pipes) running to water distribution points.[16] In contrast, we have no evidence relating to the aqueduct from which these pipes came. Taramelli suggests that, in this period, the inhabitants probably used water from the river for ordinary use, exploiting nearby springs for drinking use only.[17] It was probably water from this source that was used to supply pipes discovered within the urban area. We have, of course, no proof of the massive exploitation of the river.

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[13] Pernier (1925–1926); Sanders (1982) 156–58.

[14] La Torre (1988–89) 303–22.

[15] Pagano (1992).

[16] Di Vita (1978) 449.

[17] Taramelli (1902) 120.

The Early Imperial Period

The first recognisable evidence for the drinking water supply system comes from the Early Imperial period. During the 2nd c., Gortyn witnessed a wide-ranging programme of urban improvement, modelled on many other Mediterranean centres, which required the construction of at least two big bath complexes and two monumental nymphaea.[18] Perhaps, as part of this program, an aqueduct was provided to respond to the growing needs of the city, which had now become a provincial capital.[19] The structure was built following traditional systems of the Roman world. The general plan and structure of the new aqueduct seem to have remained substantially unchanged until the 5th c.

1. *Water capture*

The Roman aqueduct rose about 15 km from the city, next to the sources of the Zaros, on the slopes of Mount Ida (fig. 3). The capture tank was a huge rectangular chamber (37 × 5 m) with walls of thick *opus cementicium*, covered by a sturdy concrete vault, still standing at the beginning of the 20th c.[20] The wall that was set against the mountain side was taller than the others, probably in order to safeguard the ceiling against falling rocks.[21] The mouth of the *caput aquae* was set at a higher level than the chamber's floor, so that the water would be cleaned of impurities, which settle on the bottom.

2. *Transport*

The aqueduct proper was a rectangular-sectioned pipe (*ca.* w. 0.5 m and h. 1.0 m). After it reached the valley of the Mitropolianòs, it ran along the right bank of the river and then came into the city. Its route was in part gouged out from the rock, and in part supported by an unbroken wall, more than th. 2 m (fig. 4). At the entrance to a narrow gorge, which divides the two hills that dominate Gortyn from the North, the aqueduct split up, to serve both the acropolis and the lower town on the plain.

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[18] Di Vita (1986–87); (1994) and (2000).
[19] Jansen (2000) 123.
[20] Taramelli (1902) 122–25.
[21] Taramelli (1902) 123.

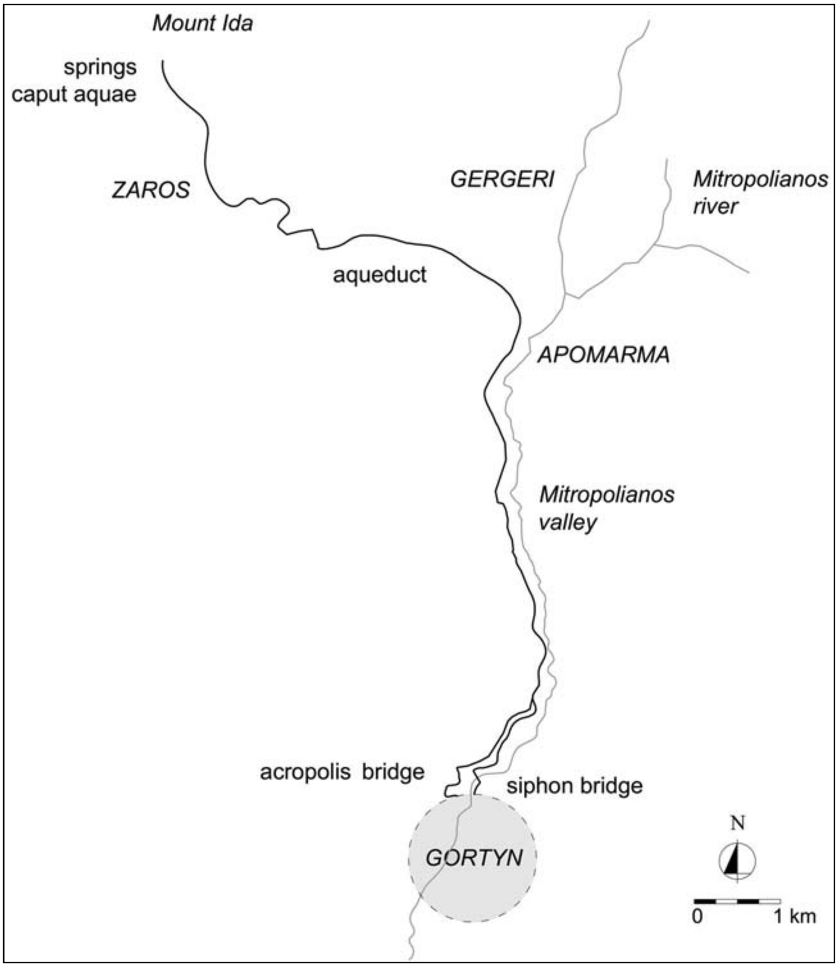

Fig. 3 Sketch of the aqueduct's line from Zaròs (springs) to Gortyn.

3. *Urban distribution*

Close to the city centre, a unquantifiable number of water towers managed an extensive system of underground clay pipes, which fed bath complexes, nymphaea, and probably many other kinds of structures.[22] Traces of this distribution system have been identified in the praetorium area, with clay pipes connected to the monumental nym-

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[22] Giorgi (forthcoming).

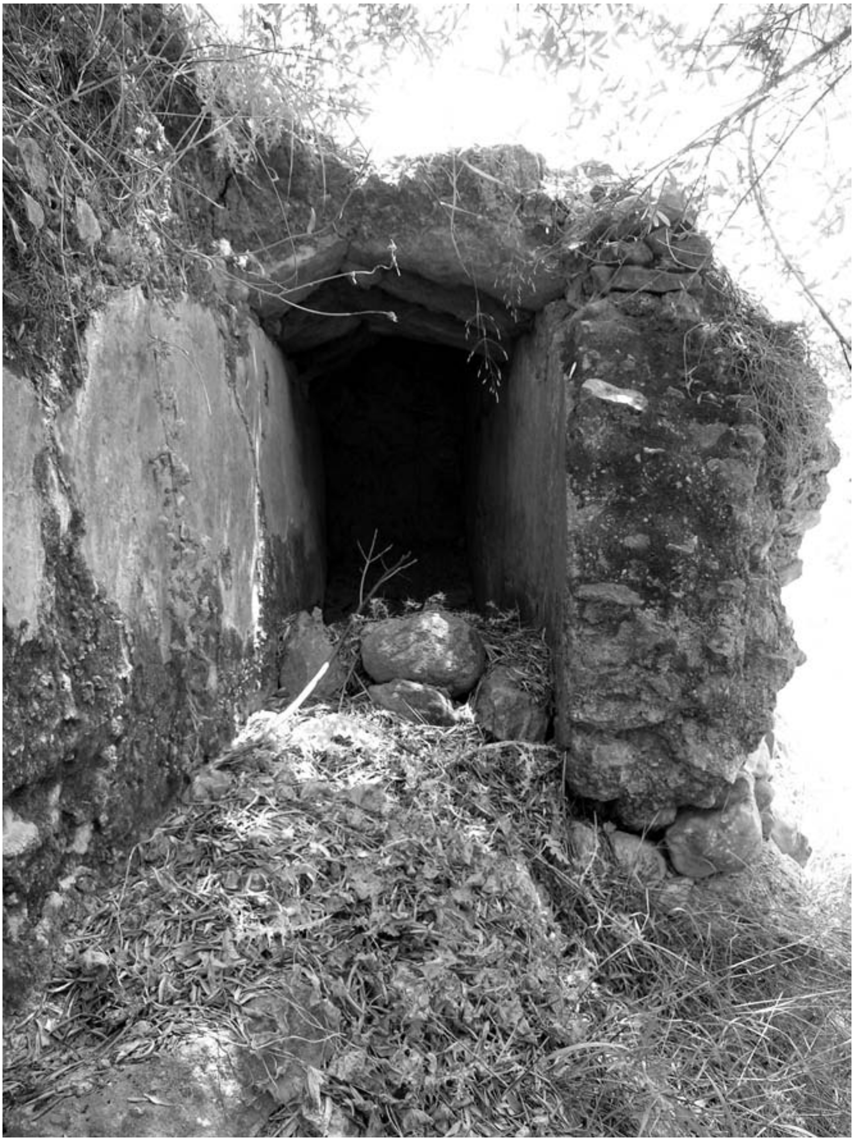

Fig. 4 Suburban aqueduct section, part gouged out from the rock, part supported by an unbroken wall.

phaeum, the Roman baths, and also in the Roman levels underlying the 'Byzantine district', in the area between the praetorium and the Pithion temple.[23]

Fourth and Fifth Centuries A.D.

The system, as conceived in the Early Imperial period, seems to have continued in use until the end of the 4th c. at least. After this date, water distribution features suffered detectable damage for the first time. Previous studies tentatively ascribe a lapse in the functioning of the waterpipe system to the period between the end of the 4th and the beginning of the 5th c.[24] According to this hypothesis, such a malfunctioning would have affected the supply system of the praetorium baths. Towards the end of the 4th c., Dositeus Asclepiodotus,[25] as *consularis*, supported a significant restoration project to convert the gymnasium-baths complex into a praetorium.[26] This plan may have been a response to a general crisis of the urban area, perhaps caused by the earthquake of A.D. 365, which—in the view of archaeological teams who previously excavated the site—seems to have caused extensive damage to the city's buildings and infrastructure.[27]

We have little useful evidence from which to reconstruct the urban distribution system during the 5th c. The only known activity concerning the aqueduct is, in fact, the restoration of an extra-urban portion, testified by an inscription dating to sometime between the end of the 4th and the beginning of 5th c. The inscription[28] was found in Apomarmà, along the route of the aqueduct between Zaròs and Gortyn. In this text, a *lamprotatos* Erennian is described as 'the builder of the new aqueduct'. It is not clear who Erennian exactly was. The epithet *lamprotatos* shows him to be of senatorial rank,[29] perhaps the city's governor, although this is not expressly stated. However, the typology of the stone on which the text is inscribed, together with its plainness, might suggest he was a private citizen, possibly an ex-consul.[30] If this were true, it might be a very interesting case of private evergetism contributing to public works in Late Antiquity, a very rare phenomenon. But whether this intervention was private or public in nature, it certainly testifies to a substantial survival of the city's urban framework, in a period when literary sources are entirely silent about Gortyn. The same conclusion could be drawn from building work on monumental and domestic structures in areas like the so-called 'praetorium' and neighbouring districts.[31]

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[23] See, respectively, Ortega (1986–1987) 161–62; La Torre (2000) 240–41 and Zanini (2006) 756.

[24] La Torre (2000) 248–49.

[25] *I.C.*, IV, 284 a, b.

[26] *Gortina V.*

[27] La Torre (2000) 248–50; De Tommaso (2000) 341–42; Lippolis (2000) 453.

[28] *I.C.* 1.31, p. 312, n. 9; Bandy (1970) 77–78, n. 47. The inscription mentions Erennian as the 'new builder' of the aqueduct (Κτίστη νέου αγωγου) and a certain Heraclius as the concrete executor of the building (Εργον Ηρακλίου έως ωδαι).

[29] About the rank of *lamprotatos*, see Jones (1964) 529.

The Water Supply System in the Sixth and Seventh Centuries

Beyond the 5th c., archaeological fieldwork on Gortyn's aqueduct has revealed a new phase, which many indications suggest should be ascribed to the 6th–7th centuries. This phase is clearly characterised by the extensive employment of a similar construction technique (the use of small irregular stony-blocks with some irregular courses of re-used bricks) that is employed only in the structures directly connected to the water distribution system, and never in any earlier building. Where the dating is concerned, it is not possible, for now, to provide more precise chronological indicators, as reliable data are not yet available. Previous studies pointed to the reign of Heraclius (A.D. 610–41), although a slightly earlier date—perhaps the second half of the 6th c.—could be supported by some considerations which I will outline shortly. The remains from this final period of the ancient water supply system are obviously the best preserved, and thus the easiest to inspect in the field. Constructions relating to water capture and transport were still working, at least partially, and were using early imperial procedures and solutions. What was innovative was the use of urban waterworks for distribution: the underground pipes seem to have partially abandoned, and instead a row of over-ground drawing points were used, taking water directly from the branches of the aqueducts.

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[30] Bandy (1970) 78.

[31] Di Vita (2000) 664; Zanini and Giorgi (2002) 901.

Elements Still Functioning

1. *Water Capture*

One of the elements still working from the Early Imperial period was the Zaròs water capture tank. Since no modifications are visible, it is plausible that the whole capture system still functioned, employing unchanged the original technological solutions, which are of course identical with those used elsewhere in the ancient world for this kind of infrastructure.

2. *Transport*

The first section of the aqueduct seems to have substantially exploited Roman structures up to the 6th c. But from the mouth of the narrow gorge of the Mitropolianòs river, on the north side of Gortyn, a number of different pipes were found, which, according to the building technique used, date from this time. Here, the aqueduct was composed of two parallel pipelines, which ran along the right bank of the river, downstream, and had a drop of 30 m between them. At the point where the aqueduct came to a very tight spot in this ravine, the higher branch went southwards, along the steep sides of a hill, to finally reach the acropolis; the lower branch split into a complex set of channels. One of these lesser channels continued in parallel with the upper pipeline, also flowing towards the acropolis: it crossed the valley of a minor tributary to the Mitropolianòs river via a high bridge, and then forked into two branches, to feed the east and west side of the hill, respectively. The second arm, instead, crossed the Mitropolianòs, via an inverted siphon, and continued, along the left bank of the river, downstream. From this point, where the *specus* was about 200 m above sea level, it fed, via a now lost distribution system, two parallel pipelines that ran halfway up the hill, to the East, to reach the furthest part of the site. From here, two pipes (diagonal, north-south oriented channels) branched off, and led to the urban distribution system. This complex system is traceable today in specific structures: the remains of a bridge with arches on the north side of the acropolis, portions of the pipelines, the remains of the siphon in the Mitropolianòs valley, and a chambered structure on the northern slopes of the city.

3. *The Aqueduct Bridge Near the Acropolis*

Next to the acropolis, on the north-western side of the hill, are located the remains of the abutments of a bridge which enabled the aqueduct to cross over the lateral valley of the Mitropolianòs gorge. When Taramelli inspected this area, he observed and marked two superimposed pipelines, interpreting them as two levels of arcades, held up by a common central supporting pillar.[32] Considering the architectural typology and building techniques used (*opus caementicium* covered by medium size ashlar blocks, very similar to those used in other Roman buildings, like the 'Small Theatre' near the Pythion, or some parts of the praetorium baths),[33] this bridge seems to date from the Roman period. However, it was very likely to have still been in use in the 5th to 6th centuries, since it seems to have been the only way for water to reach the acropolis, where some Early Byzantine cistern-fountains remain clearly visible.

New Elements

1. *Pipelines*

Modern landslips have badly affected the pipelines, making it difficult to establish a chronological sequence. Some portions have collapsed into the pebbly riverbank, so they are conspicuous only by their absence. They are, in fact, engraved on the slopes of the hills running along the Mitropolianòs river, following the route of the aqueduct. But although the pipelines are partially preserved, it is not possible to distinguish for certain all phases, because of the great continuity in the technology peculiar to this kind of structure. Without glaring differences in building technologies, not even direct analysis of a single portion can help us distinguish 6th–7th c. reconstructions of previous pipelines. For this reason, coating mortars will be sampled: their differential analysis, not yet undertaken, will provide new elements to date any single portion of the aqueduct.

2. *Siphon*

With much more reliability, it is possible to date the last reconstruction of the siphon bridge to the 6th or 7th c. This was built to allow the aqueduct to cross the Mitropolianòs river, using undoubtedly one of the most advanced technological solutions in the whole system.[34] This structure was already working in the Early Imperial period, but what can actually be seen today are two lateral abutments, dating to the 6th or 7th c. (fig. 5). This date can be established from the fact that the abutments were built employing the same building techniques used in all equivalent hydraulic structures within the city belonging to the latest phase of the system (such as the cistern fountains). The structure worked as an inverted siphon, following the traditional principles of ancient hydraulic engineering.[35] On leaving the main aqueduct, this canal piped water into a waterproof chamber. From there it sank through a steeply inclined drain, leading to a drop of 11 m. This system provided the propulsion necessary to push the water up on the opposite side of the valley, to reach a slightly lower level than that at the start. Here, thanks to an open basin, the water pressure was lowered and then fed into new pipes.

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[32] Taramelli (1902) 136.

[33] Rocco (2000) (praetorium); Ghedini, Bonetto and Veronese (2003) ("Small Theater" near Pythion).

[34] Taramelli (1902) 131.

In the 6th–7th c., this system was probably restored, perhaps after a landslip. So, a new channel was built to link the conduit coming

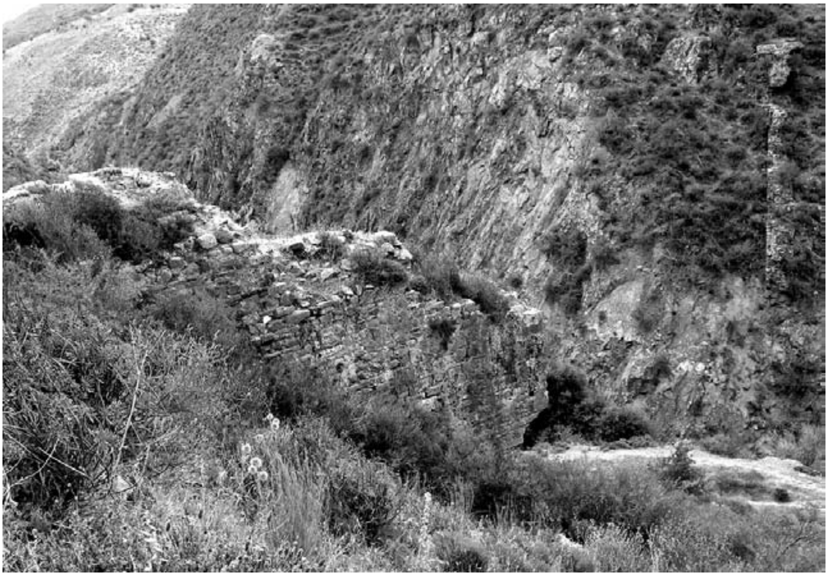

Fig. 5 Siphon bridge from the north side of the Mitropolianòs gorge.

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[35] Vitr. *De Arch.*, 8, 6.5–6. For ancient water technology in general, see Wikander (2000). On siphons, see Hodge (1983); (1985); (1992) 428 n. 43 and (2000).

from the valley with a new gathering chamber. This last structure was built at a lower level than previously, with its thick walls incorporating pre-existing structures. On the eastern riverside, the bridge abutment continued to function, as it was built upon firmer ground where landslips were less frequent.

3. Kamarakia

Another distinctive aspect of the transport system was an impressive chambered structure with butresses. It was built on the hill that rises up on the north-east side of the city. This structure has not yet been fully investigated, but its modern place-name, *Kamarakia* (the Greek word for 'chambers, or cisterns'), probably points to the ruins of a decompression chamber, designed to reduce the water pressure in the pipes and redirect its flow into descending branches. To the East, there is also evidence of a very similar structure, at the point where the aqueduct reaches the eastern edge of the Early Byzantine city. That both structures date to the 6th–7th centuries, seems to be confirmed by the building technique, which, once more, appears identical to that employed in the cistern-fountains.

4. *Urban Distribution (branches A, B and C)*

From the Early Imperial period, at least three parallel branches led from the two E-W parallel aqueducts, moving off in a south-westerly direction: respectively (from west to east), branches A, B and C. They were set 200 m apart, and brought water by gravity down the slope and into the city. Only branches A and C were still working in the 6th to 7th centuries: extensive re-building work is testified by the building technique, which is almost identical to that of the Early Byzantine cistern-fountains; moreover, at the foot hills in the northern part of the site, some cistern-fountains are directly connected with these branches. Branch C, the best preserved, reaches the city via an arched route crossing over the praetorium's water tower (fig. 6). It follows the road west of the praetorium and reaches a line of cisterns, which are presumed to be the terminus of the aqueduct,[36] at the southern edge of the site, next to the Megali Porta bath complex.

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[36] Pagano (1992) 281.

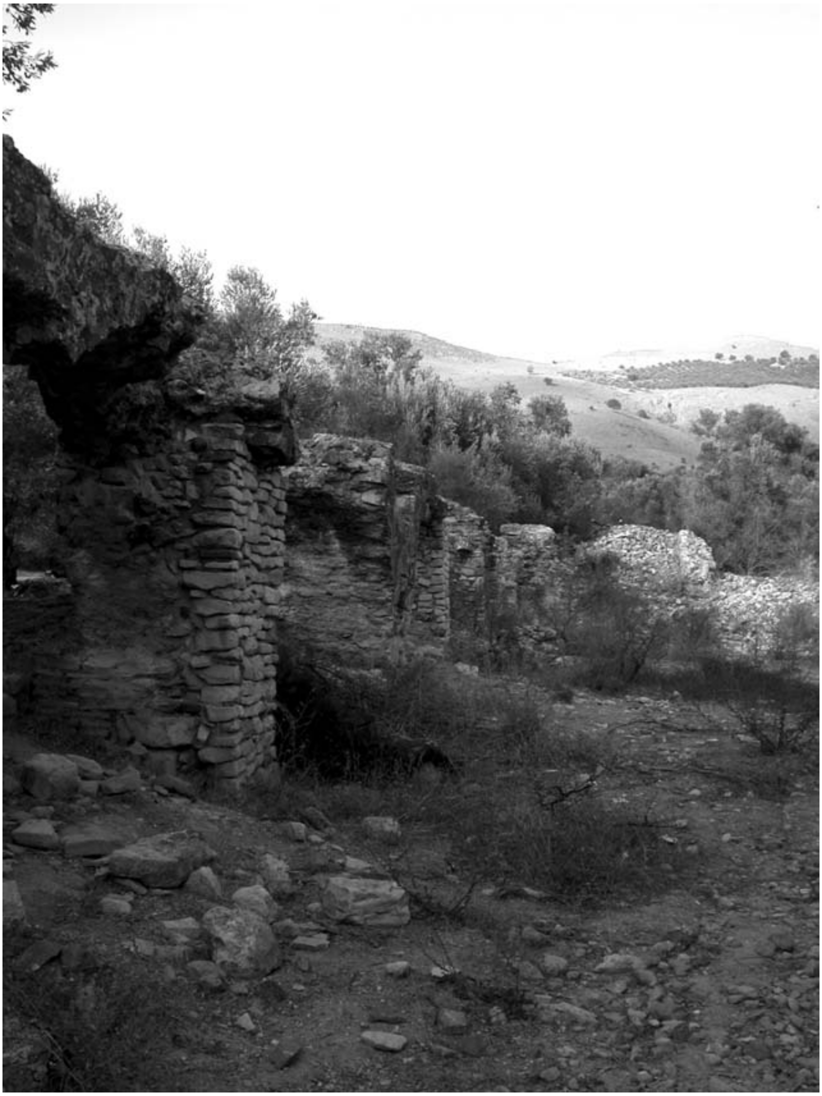

Fig. 6 The urban aqueduct: branch C arcades.

Only the first section of branch A can now be seen. Unlike C, it was built with solid walls. When it reached a second Roman *castellum aquae* (set on exactly the same latitude as that of the praetorium), it probably changed its solid structure into arcades; these are now no longer visible, though they were clearly depicted in the 18th c. by J. Pitton de

Tournefort, who drew a series of arches near the Mitropoplianòs river. There is no reason to doubt this iconographic source, as it is absolutely reliable for all other structures relating to the water system.

Branch B was probably not restored in the 6th to 7th centuries:[37] it has, in fact, typically Roman stony-block walls and no connection with cistern-fountains. Another descending branch (D?) was located in the eastern part of the site, and was connected with one of the *lacus*[38] seen on site. However, to date, there is no other archaeological evidence of its existence. Forthcoming investigations on the site will seek to examine this structure. Other branches that were still working were probably connected by further transversal branches known from traces on the ground. They may have been recognised by Buondelmonti, who described a city wholly furrowed by aqueducts.

A series of minor channels led off from these aqueduct branches. They were connected to different urban distribution points. Fortunately, two different markers characterise the water distribution system in this last phase: segments of pipes made from *spatheia* and a network of more than 50 cistern-fountains typical of the Early Byzantine city.

The Cistern-Fountains: Common Characteristics and Distinctive Features

More than any other feature, the cistern-fountains characterise Gortyn's water system in the late period. 51 examples have been detected so far, irregularly spaced within 80 urban ha, and organised in clusters that largely coincide with the areas of the acropolis, the praetorium and Megali Porta. Some more distant and isolated examples have also been recorded. All the fountains fit within the same building typology, based on the deployment of stony-blocks and bricks, also used for the Early Byzantine aqueduct's walls. In recent years, two of these fountains were the subject of archaeological investigation, which enabled us to reconstruct their morphology and operation. These structures were fed directly from the aqueduct's *specus* (the main channel, which runs on top of the aqueduct's walls) and built with a rectangular basin for water storage; this was covered by a barrel vault (fig. 7),[39] coated with hydraulic mortar, and was reinforced with ribs in the inside corners,

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[37] Di Vita (1984) 236–40.

[38] A sort of large open air reservoir.

[39] For a preliminary graphic reconstruction of the fountain, see A. Ortega in Di Vita (1984) figs. 36, 37.

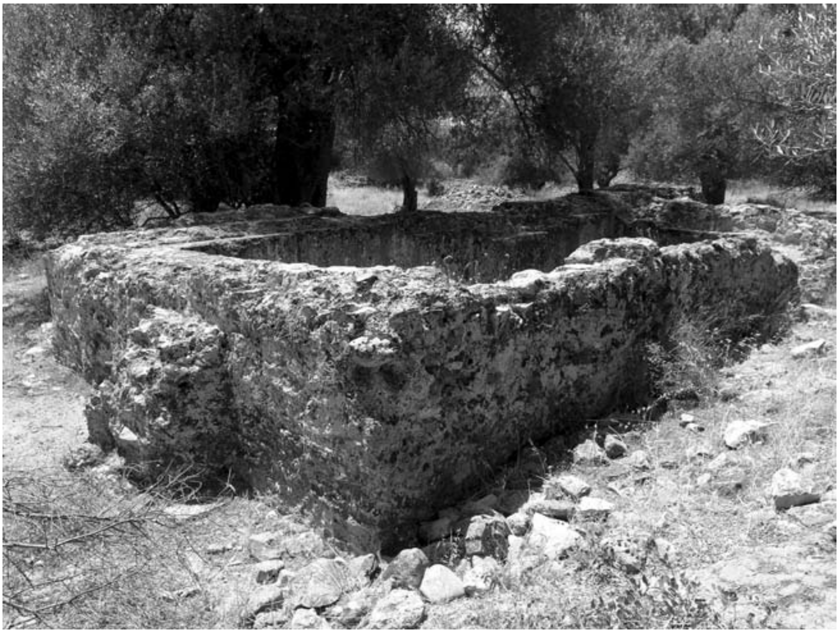

Fig. 7a

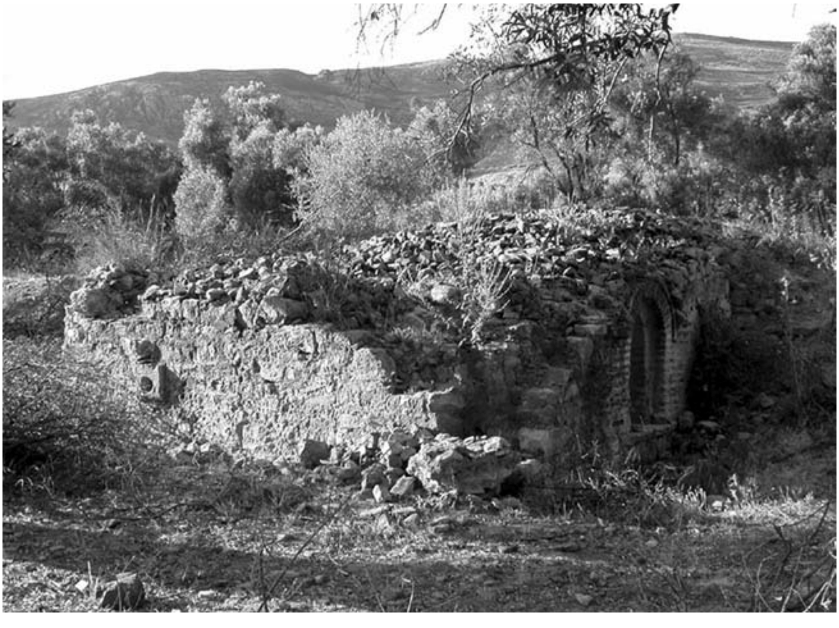

Fig. 7b

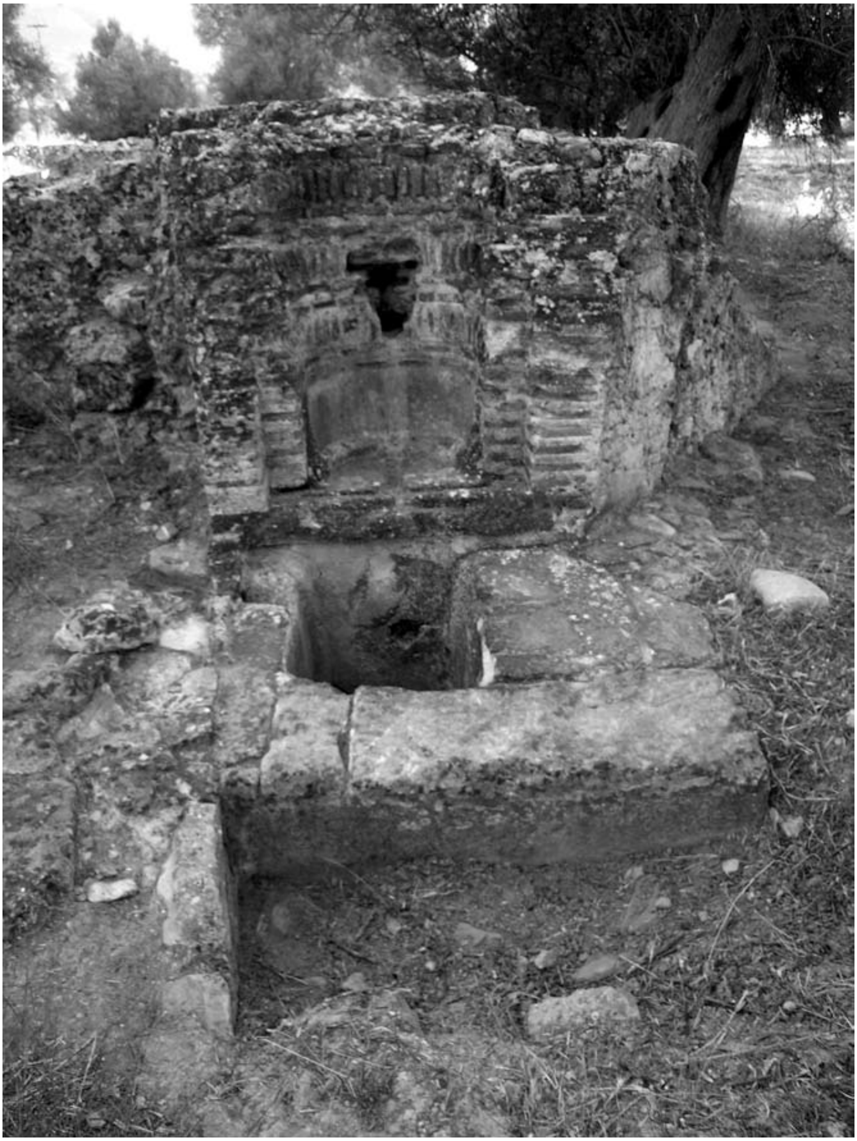

Fig. 7c Examples of cistern-fountains: chamber, niches with geometric decoration, basin for animals.

in order to strengthen the stonework at the wall junctions, which were subjected to outward thrust from the pressure of the water.

On the exterior of the cisterns, niches (between one and three in number) were set, with geometric decoration on the bricks. Inside these niches were drawing points, with taps to regulate water flow. The dimensions of the basins vary. Out of a 20 per cent sample, basin capacity varied from 48 to 62 m^3. Three or 4 large cisterns (hundreds of cubic metres in volume) should also be added to the network of cistern-fountains. Because these were not equipped with drawing points, they were probably made to store water for emergencies; they were located in an important position within the urban plan: upon the acropolis; just next to the baths of Megali Porta; and by the two major churches of St. Titus and Mitropolis.

1. *The use of residual water*

Some fountains incorporate, as part of their original design, systems for the re-use of surplus water. This was piped into basins and wells, probably used as washtubs or drinking troughs. Thanks to the high level of preservation of some fountains, it is possible to examine this system of re-use in detail. Fountains no. 4 and 7 are particularly interesting cases.

Fountain no. 7 is located on the southern side of the praetorium complex. It has a large basin, which has internal steps leading to its bottom, permitting good maintenance. Water arrived on the eastern side of the tank and was directed towards the main drawing point on the southern front and into the cistern behind via two lead pipes. The unbroken water flow seems to have been mainly directed to the straight drawing point, and perhaps regulated by a tap. When the tap was closed, water filled the tank, thereby forming a reserve supply. Once the cistern was completely full, surplus water leaked from above, feeding a second fountain on the east side, and finally exited the southern side via a pipe. The main drawing point was framed by a semi-circular niche, faced with bricks and forming a decoration of alternate bands of bricks laid flat and on their edges; flutes for slots testify the presence of a slab to prevent animals from reaching the clean water. Animals could bathe in water in a basin at ground level, and drink from residual water coming through a hole in the slab. From there, water was probably conveyed into sewers which have not yet been investigated in any detail.

Fountain no. 4, which was located within the praetorium area, has a basin on one side, probably to collect surplus water from the main tank. The basin, standing in an open area, has a brick floor (of *bipedales*) and walls coated with hydraulic mortar. It seems to have a drain, leading towards a nearby street running along the west side of the praetorium. On the back of this fountain, some Early Byzantine shops/houses, between the praetorium and the Temple of Apollo Pythios,[40] still show traces of clay pipes in their walls; they might once have carried water from the tank (perhaps a washtub or a little spa basin) towards the street, where a sewer was probably to be found.[41] Along this route, pipes passed into artisanal establishments that used water for productive purposes.

Hints of a close connection between craft activities and an immediate water supply also come from the Megali Porta baths area, close to the southern edge of the city, where a large number of fountains were situated. Between the 6th and 7th centuries, part of the ancient baths were re-used as residential dwellings and craft-producing plants, as testified by archaeological finds retrieved in surveys (such as amphorae, cooking pottery, furnace rejects and iron slags).[42] Modifications made to the original settings of fountains testify to their different uses with the passing of time. An interesting case is, once again, fountain no.4 in the praetorium district. Not long after its construction, a branch was created, leading from the basin of the main cistern to a glass workshop, set up in one of the chambers to the rear (fig. 8).

The Cistern-Fountain System

As has already been said, the fountain network did not completely cover the whole urban area in the 6th to 7th centuries. The cistern-fountains were concentrated in three distinct groups, which coincide with the areas of the praetorium, Megali Porta and the south-eastern side of the acropolis. The presence of fountains in these parts of the city reveals that people still lived there in the 6th to 7th centuries

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[40] The excavation data from the praetorium are currently being published. Preliminary reports are available in the *Annuario della Scuola Archeologica Italiana di Atene*.

[41] Belli Pasqua and La Torre (1994–1995) 143.

[42] Masturzo and Tarditi (1994–1995) 276–77.

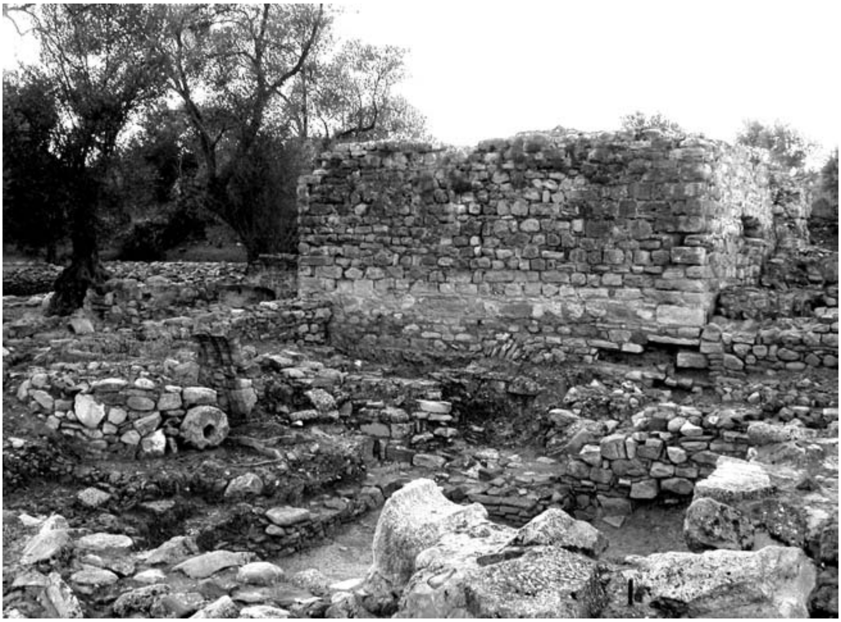

Fig. 8 Fountain no. 4 by the praetorium,
showing branch from cistern to glass workshop.

(fig. 9). Archaeological research in the praetorium area also testifies to a continuity of occupation of some spaces, at least until the late 7th c.[43] The same chronological period is attested by surface surveys in the area of Megali Porta.[44] In contrast, very little is known about the south-eastern side of the acropolis. The site seems to testify to unbroken occupation from the 7th c. B.C. (the date of the construction of a major shrine) maybe to the 7th c., to which time the fortification wall 'of Heraclius' is conventionally dated.[45]

Archaeological data from early 20th c. surveys[46] point to the continued occupation of the acropolis in the 7th c.; however, they do not tell us anything about the nature and morphology of this settlement. In quarters near the Mitropolianòs river, where the Christian basilicas of Mavropapa, Mitropolis and St. Titus rose, no water distribution grid

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[43] For a general summary of the main topographical and chronological phases, see *Gortina V* (2000).

[44] Masturzo and Tarditi (1994–1995) 306.

[45] Rizza and Santa Maria Scrinari (1968) 90–96.

[46] Taramelli (1902) 140–58.

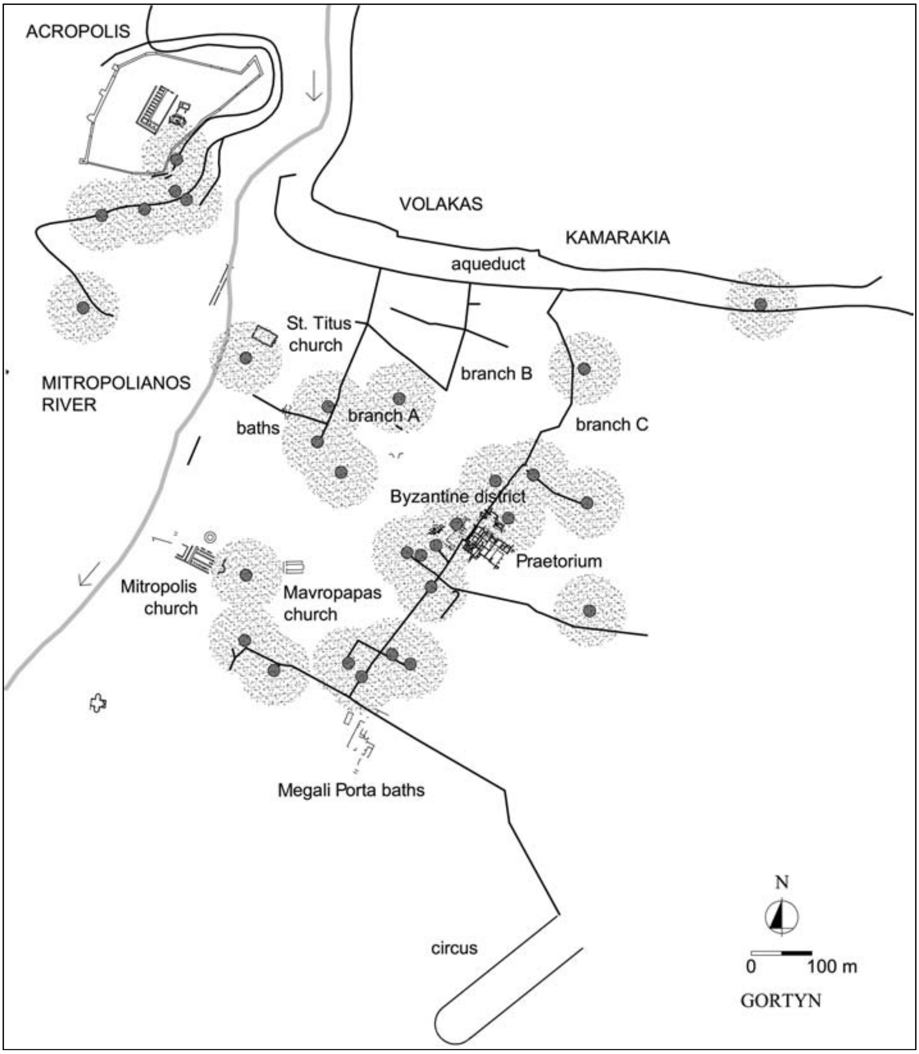

Fig. 9 Map of fountain network, suggesting inhabited zones of 7th c.

has been detected on the surface. However, some clay pipes made from *spatheia* were found during investigations along the road to Mitropolis, and these have been dated to the 6th c.:[47] similar *spatheia* ductwork has also been found in the final occupation phases of the praetorium[48] and in stratigraphy of the second half of the 6th c. from the Byzantine quarter around the Temple of Apollo Pythios (fig. 10).[49] In the Mitropolis quarter, pipes could have been supplied by the aqueduct branch known only from Pitton de Tournefort's drawing, in which a sequence of arcades appear to have run close to the river, although no archaeological evidence of these has been found, to date. In this area of the city, there is no archaeological evidence for cistern-fountains, normally present in the other branches of the Early Byzantine aqueduct. This suggests that the urban distribution system was articulated: in the main part of the city, the water supply was assured by surface access points (cistern-fountains); in the area around the Church of Mitropolis, a more refined system, perhaps based on undergound pipes (*spatheia*) served a network of smaller fountains, maybe directly connected with larger private houses.

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[47] Allegro (1988); Rendini (2004); on typology, see Rendini (2006).
[48] Lippolis (2000) 450–52.

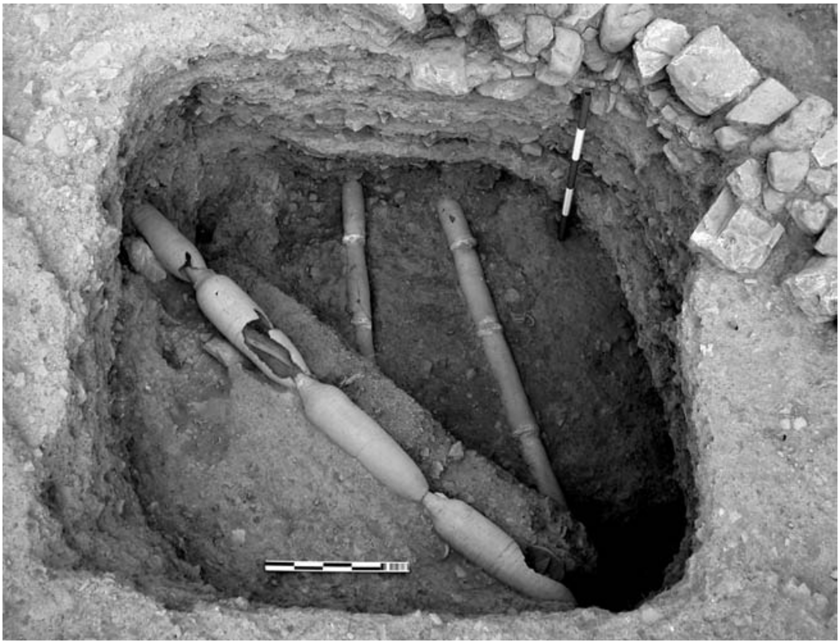

Fig. 10 Two different aqueduct pipes (with Roman *tubuli* and Byzantine *spatheia*) in a 19th c. archaeological trench.

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[49] Zanini (2006) 756.

Dating Problems

Introduction

The water supply system of 6th to 7th c. Gortyn should be interpreted as a unitary urban network, in which all individual elements, such as pipes or fountains, were very closely connected to each other, and interdependent. The unity of the system is particularly clear from the building technology of the structures connected with the aqueduct. Despite the generally strong continuity in construction technology and building materials, especially in the case of Crete, Early Byzantine hydraulic structures in Gortyn are—as stated earlier—clearly recognisable as a distinct group with their own unique building technology, which had never been used before in any other structure within the city. So, it is plausible to think that the aqueduct and waterworks were rebuilt as part of the same unified operation. The 'originality' of the building technology used also suggests the employment of foreign workers from regions far from the city's cultural environment.

Structural and functional connections between the aqueduct branches (A, B and C) and the network of fountains is undoubtedly a second and strong element of unity. The fountains received water directly from the aqueduct's *specus*. Further, the aqueduct would have had no reason to exist without such drawing points, from which the inhabitants could physically access the water. The system's homogeneity provides a fundamental basis for a chronological paradigm and, finally, for dating the whole of Gortyn's aqueduct. Indeed, this homogeneity allows one to combine single pieces of dating evidence, and then to extend them to the system as a whole.

The Contribution of Archaeological Research

Constructing a chronological paradigm for the 6th to 7th c. aqueduct is, however, not a simple task, on account of the fragmentary nature of the available data. The silence of the written sources adds to the partiality of archaeological surveys and reinforces the argument for topographical discontinuity, though of course investigations have necessarily been focused only on some portions of the city. At Gortyn, some branches of the aqueduct and the cistern-fountains seem to be among the most recent structures in the stratigraphy of the urban landscape of the city, which was apparently inhabited, although in a somewhat restricted manner, until at least the 8th c. Some new information has been obtained from exploratory archaeological research. The stratigraphic sequence of the *castellum aquae* on the north-western side of the praetorium seems to indicate that the last recognisable phase of this structure dates to between the 6th and the 8th c.[50] In this time, it seems to have lost its previous distribution function, and was used as a support for the arcades of aqueduct branch C. This branch, in fact, crossed over the structure and then continued towards the southern side of the site.

A few segments of the city's water supply system were considered by recent archaeological investigations.[51] Branch C is one of these, although only a very short section was examined. A Justinianic *follies*, dating to A.D. 558–59, was found lying upon the foundation plinth of one pillar.[52] This suggested to the excavators that the aqueduct dates to the second half of the 6th c. Of course, although the coin's presence provides a *terminus post quem* for the building of the aqueduct, it cannot determine a more precise chronological range. Moreover, it must be born in mind that the particular position in which this *follis* was found means that it could have been discovered out of context and is not, therefore, necessarily connected with the pillar's foundation.

Another useful element in establishing an absolute chronology comes from fountain no. 5. A ceramic sherd (an example of the so-called Early Byzantine painted ware), apparently not attested in Gortyn before the 7th c., was found inside one of the floor layers.[53] This fact convinced the excavators that the fountains could date to the time of Heraclius.[54] One must, however, note that the fragment in question comes from a floor surface affected by subsequent occupation and re-construction work. Therefore, it could possibly reflect traces of a later intervention, perhaps the restoration of the floor. Finally, it should be mentioned that reliable stratigraphical sequences are not yet available from which to date this class of pottery.

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[50] Di Vita (1994–95) 357–60.

[51] Belli Pasqua and La Torre (1994–1995).

[52] Belli Pasqua and La Torre (1994–1995) 159.

[53] Di Vita (1984) 226.

[54] Di Vita (1991) 170–72; Pagano (1992) 281; Di Vita (1994) 831 and (2000) 664.

The Problematic Inscriptions of Georghios and Heraclius

Inscriptions, of course rare, pose some interpretative problems. Epigraphy has not yet offered any explicit evidence of an imperial-public involvement in the last phase of the water supply system. Rather, it attests to less important operations concerning water, limited to certain structures. Religious authorities, more precisely bishop *Georghio*s (otherwise unknown in the history of Gortyn), seem to have been at the heart of this building activity. An inscription,[55] said to date to the 6th c. on palaeographic grounds alone, describes him as the one who gave water back to the city and restored a cistern. The same *Georghios* is perhaps recorded in another inscription[56] from Gortyn, known from a later manuscript.[57] This text records the restoration of a floor (πάτος) and a church (ναός)[58] or, according to another reading, a waterwork/aqueduct (νιλος).[59] While there are objective difficulties in associating the first inscription with the 6th to 7th c. restoration of the city's distribution system, these inscriptions clearly reveal the central role of the city's religious leaders in the management and maintenance of public works in 6th c. Gortyn. This is, of course, a phenomenon attested at the same time in many other cities of the empire.[60]

Even more difficult to interpret is the acclamation to Heraclius and his family, which is frequently associated with the aqueduct's last phase. These inscriptions were carved upon four columns in front of the praetorium's nymphaeum.[61] Previous studies have, so far, seen them as evidence for the city's final reconstruction after the supposed earthquake of A.D. 618,[62] when Gortyn was supposed to have been rescued thanks to the Emperor's direct intervention.[63] Further, the nymphaeum's conversion into a covered cistern[64] has traditionally been dated to the time of Heraclius, together with the restoration of the distribution system, and associated with the network of fountains. Considering their textual content, however, there are no elements in any of the 4 inscriptions to necessarily associate the Emperor with any building activity in the city. Taking into account the acclamatory character of the inscriptions[65] it seems more probable that the inscriptions simply marked a focal point in the urban landscape, just in front of the praetorium, and were not necessary connected with the actual re-building of both the praetorium and the nymphaeum.

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[55] *I.C.* 4.465.

[56] *I.C.* 4.461; Bandy (1970) 61–63, n. 32.

[57] *Vat. Graec.* 1759, f. 135 *r.*

[58] Guarducci (1950) 399.

[59] Bandy (1970) 62 prefers νιλος (aqueducts but, in association with πάτος (floor), this could be translated as 'cistern').

[60] Brandes (1999) 29–30.

[61] *I.C.* 4.512 (A–D).

[62] Di Vita (1979–80) 439, (1985) 139 and (2000) 664.

[63] De Tommaso (2000) 284–383, 270.

[64] Maiuri (1914) 127; Ortega (1986–87) 160.

A Working Hypothesis and Future Research

Considering all the elements as a whole, it is possible to suggest that the aqueduct's final phase can be dated to the late 6th to 7th centuries, when Gortyn changed from merely being a city composed of relatively elegant buildings, to a town in which craft activities began to occupy the monumental centre. It is, however, extremely difficult to fix a date within 50 years, considering the evidence available for the period in question. Further work is needed in order to increase the quantity and quality of dating evidence; this is particularly likely to come from the excavations around the praetorium, and in the Early Byzantine quarter of the Temple of Apollo Pythios. The interaction of all the elements that these open area excavations provide—whether stratigraphical, topographical, chronological or typological—probably offers the most useful way of establishing a reliable chronology for the final phase of urban life in this area. Starting from this point, a research program, organised on a city-wide scale, could better understand the aqueduct's diachronic sequence and, as a consequence, the history of the whole site.

Technology for Living and Working

The Water System as an Archaeological Marker of Urban Change

One of the most interesting aspects of the study of a water supply system is the possibility it provides of examining a cross-section of everyday life. Concerning Gortyn, both fountains and aqueduct branches can serve as reliable archaeological markers of the development of the urban fabric, from many points of view. The distribution of fountains is, in fact, a good starting point from which to focus on urban transformation. As suggested above, both their presence and their absence can tell us much about a settlement's structure.

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[65] Roueche (1984), (1999 a) and (1999 b).

For Gortyn, the beginning of the 7th c. was a critical moment in the evolution of the city. Archaeological excavations, currently in progress, are revealing a town in which the monumental areas were increasingly falling apart, but in which disused public buildings, such as the praetorium and the Megali Porta were given over to artisanal occupation. While standards of living progressively declined, the solid walls of the aqueduct probably crossed suburbs or almost deserted districts. On the contrary, the arcades of branches A and C seem to have run through one of the most inhabited areas. They could, this way, ensure the passage from one side of an aqueduct to another, and supply water to an area which, though not central, was still inhabited.

Preliminary Consumption Estimates

Studies of fountain distribution can reveal much more than which areas of the city people decided to live in. By simply thinking about the obvious connection between water availability and human activities, it is easy to pass from an analysis of monuments to a study of human life. More precisely, one can try to understand who and how many people might use an aqueduct's drinking water. It is possible to estimate this quantity by taking into consideration two different parameters: the flow from the spring that supplied the aqueduct, and the capacity of the conduit that brought water into the city. Both parameters are quantifiable, for different reasons. On the one hand, the output of the Zaròs springs is known because they are still used for industrial purposes. On the other hand, the pipes are still partly preserved along the route leading into the town. This allows a good evaluation of their capacity.

At present, the amount of water supplied by the Zaròs springs varies from a maximum of 17,000 to a minimum of 6,000 m^3 per day. The remarkable depth and flow of this spring allows us to hypothesise that its capacity remained substantially unaltered through time. Therefore, the present evaluation is likely to reflect the actual flow of water from the spring in both the Early Imperial and late antique periods. If we calculate the flow of water by considering the dimensions, average slope, and roughness of the pipes, we obtain a maximum estimate of *ca.* 17.000 m^3 per day. This result is consistent with the present flow of the spring. Thus it is possible to state that the water system was planned in order to convey to the town all of the water supplied by the spring. However, this does not mean that all the water of the spring actually arrived in the town. Along its 15 km long path, there were probably a number of different discharges. The water would have been used for irrigation, by workshops, and in mills. Furthermore, accidental leaks are likely to have occurred. The latter are particularly difficult to estimate. At present, large urban aqueducts (such as the aqueduct of Rome) are only able to convey 60–70 per cent of their spring flow to its final destination. Taking these figures into consideration, it is, therefore, possible that the quantity of water received by the water towers of Gortyn which was actually available to its population ranged between 3,500 and 11,000 m^3 per day.

But what was the population of Gortyn in Roman times? In the absence of any reliable demographic indicator, we could tentatively estimate the population of the city[66] according to the large size of the archaeological site (more than 170 ha), and an estimate of population density based on the hypotheses of modern scholars of the Roman world, who suggest that 100–200 inhabitants per ha was normal.[67] In this way, we could posit a hypothetical figure of 17,000–34,000 people, a number which is, by and large, reasonable for a city of such physical, social and economic dimensions.[68] Taking into account a median average for both population and water supply, we might settle on a figure of some 25,000 people and 7,000 m^3 of water per day. This would suggest the theoretical availability of some 280 litres *pro capite pro die*: a quantity equal, if not greater, than that available on average today in western cities.

This quantity is much greater if we consider the fact that daily water consumption in the ancient world was, by necessity, far more limited than in the modern world. Two points can be made in support of this argument. First, in the 19th c., the planners of the waterworks of European cities worked on the basis that daily water usage *per capita* was 50 litres.[69] Second, the daily water usage estimated for agricultural societies around the beginning of the 20th c. was 15–20 litres (a bucket) for each individual. This leads us to conclude that only a small part of the water available daily (possibly some 1.000 m^3) was used for individual consumption. The rest of the water would have probably been directed towards the baths and monumental fountains, which were particularly numerous in the early imperial city.

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[66] On the difficulties of estimating ancient populations see Chamberlain (2006).

[67] Hassan (1981) 66–67.

[68] For the concept of 'cité moyenne' applied to the Late Antique/Early Byzantine world see now Morisson (2004) 197; see also Morrisson and Sodini (2002) 174.

[69] Bruun (1991) 99, 104, n. 35 and (1997) 126–27, n. 19.

What can be said with regard to the later period? It is clear from the epigraphic and archaeological evidence of restoration work on the aqueduct, that the water system remained in use, and was substantially unaltered between the 4th and the late 6th–7th centuries. Given that the size of the city remained unchanged in this period, we may assume that its population was also stable. Of course, the 'quality' of the water available for everyday use may well have diminished, though we do not know for how long and in what manner the thermae and the nymphaea continued to be used. However, the necessity of dealing with a large quantity of spring water may have encouraged the maintenance of the aqueduct, which was a complex and integrated system, and could not, therefore, be partially altered without endangering the whole system.

So, if we accept the likelihood that late antique Gortyn was supplied with roughly the same mean quantity of water as the Roman city, we may then ask ourselves how this considerable amount of water was managed. As in Roman times, it was partly stored for individual needs, and partly delivered to a system of thermae and nymphaea—at least, to those parts of the system that were still working; it was partly exploited for craft trades, and partly stored in huge open cisterns, which were located near the main churches, and up on the acropolis. Taken together, these cisterns—a large open *lacus*, accompanied by large, medium and small cistern-fountains—would have ensured considerable water storage space (more than 8,000 m^3). This implies that the city could be supplied for long periods of time, even in the event of its water supply being totally cut off.

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LATE ANTIQUE URBAN STREETS AT SAGALASSOS

Femke Martens

Abstract

Since 1998, a programme of street test soundings has been carried out at Sagalassos (South-West Turkey) to investigate the urban development of the town and the evolution of its street network.[1] Combined with the evidence from large-scale excavations, and geophysical and architectural surveys at the site, this research has painted an accurate picture of ancient street design in this Roman town. Given that the remains of late antique Sagalassos are particularly well-preserved, the evidence also casts light upon the maintenance of the urban infrastructure of this classical city, which gradually became a decaying town from the second half of the 6th c. A.D.

Introduction

Investigating a Network of Urban Streets

According to its basic definition, the term, 'urban infrastructure' encompasses street systems, water conveyance systems, water-related structures, and (central) open spaces or squares. Of these components, urban streets generally seem to have received the least attention in archaeological studies.[2] In many excavations of classical sites, street networks and elements of water systems are still largely neglected in favour of monumental buildings and architectural elements of greater aesthetic value. General overviews which include sections on ancient streets discuss aspects such as building technologies, and the use and significance of these traffic arteries, but mainly deal with extra-urban

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[1] The author would like to thank Prof. Dr. M. Waelkens for his useful suggestions in setting up the field work for this research and for his continuous support.

[2] For a recent acknowledgement of this situation, see Poehler (2006) 53–54.

L. Lavan, E. Zanini, and A. Sarantis (edd.) *Technology in Transition A.D. 300–650*
(Late Antique Archaeology 4–2006) (Leiden 2007), pp. 321–365

roads,[3] while studies devoted entirely to urban streets are hardly ever exhaustive.[4] As a network of streets forms the blueprint of any urban plan, existing studies of urban street systems often aim to reconstruct the evolution of town plans,[5] rather than present an all-encompassing view of all aspects of local street design, including technical factors.[6] Therefore, research on urban streets is still in need of a systematic and basic overview of technical data, taking into account possible chronological changes, issues of maintenance, and particular local concepts of urban street layout. Ancient technical literature is not very helpful,[7] so that it is necessary to turn to archaeological sources. It is clearly easier to study urban street systems—as well as water networks—[8] at sites which have been extensively excavated. However, large-scale excavations of entire urban settlements are no longer feasible from a financial perspective or with regards to the responsibility towards conservation.[9] For this reason, a programme of test soundings can be a preferable research strategy.[10] Non-destructive research techniques such as geophysical surveys may also offer a solution, especially in the reconstruction of urban plans.[11]

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[3] See *inter alia* Forbes (1965), although this study also includes a brief section on city streets and urban traffic; Pékary (1968); Radke (1971); Casson (1974); Schneider (1982); Heinz (1989); Chevallier (1997); For a conceptual approach, see Laurence (1999).

[4] The study by Geseman (1996), although not very explicit on technical detail, is unique in the sense that it investigates the function and chronological evolution of the urban street system of one town—Pompeii—by interpreting its streets as unitary architectural wholes, including different elements such as pavements and the water networks, street fountains, sanctuaries and adjoining facades. MacDonald (1986) also uses a comparable conceptual approach with streets functioning as armatures within the urban fabric. For legal aspects of the use and maintenance of ancient streets, see Saliou (1994); van Binnebeke (1997); Saliou (2003).

[5] For instance, for a reconstruction of the street plan of Constantinople mainly based on ancient topographical literature, see Berger (1997); Berger (2000).

[6] For a study describing the technical details of Early Byzantine street construction at Caesarea Maritima, see Vann (1982).

[7] There are no Greek or Roman handbooks on ancient road building. Vitruvius, for instance, is more explicit on domestic floors than on street paving. A 1st c. A.D. text by the poet Statius with a detailed description on this topic seems to be an isolated example, see Forbes (1965) 152; Chevallier (1997) 108–109.

[8] Jansen (2000) 111, 124; Martens (2006) 180.

[9] Dyson (1993).

[10] The street system of Pergamon e.g., has been investigated since 1986 by means of extended *Gassensondagen*, see Wulf (1994) 136; Wulf (1999) 34–35, n.17; Radt (1999) 83–85, 335.

[11] Geophysical survey is becoming increasingly important in the investigation of street systems. For Aphrodisias, see Smith and Ratté (1997); Ratté (2001); for Ephesus, see Groh (2001); for Ilion see Jansen and Blindow (2003), or closer to Sagalassos, for Pisidian Pednelissos, see Vandeput and Köse (2003).

However, to establish a chronological framework, analyse particular technical factors, and investigate the maintenance of an urban street layout, excavations remain essential.

Obviously, the design and development of a network of streets are closely connected to the layout of the water network. For Sagalassos, an elaborate chronological, morphological and functional study of the elements of the water infrastructure has been carried out, the results of which are published in multiple articles.[12] Therefore, the water network of the site will not be discussed in great detail here, and only in relation to the general evolution and maintenance of the urban infrastructure in late antique Sagalassos.

As a contribution to bring to an end an important hiatus in the study of urban infrastructure, the purpose of this paper is to offer an all-encompassing view of the layout and maintenance of the network of streets in Sagalassos. It will be based on excavations, test soundings, architectural survey and geophysical research, while taking into account the strengths and weaknesses of these research strategies and restrictions imposed by the condition of the archaeological record.

The 'Sagalassos Archaeological Research Project', the Research Strategy and the Nature of the Evidence

Sagalassos (Pisidia, South-West Turkey) was built on the south-facing slope of a mountain crest in the western Taurus. Since 1990, the site has been studied by an inter-disciplinary research team directed by M. Waelkens (Katholieke Universiteit Leuven), with the aim of reconstructing all aspects of the development of the town and its territory in relation to the natural environment.[13] Archaeological research initially focused on the monumental centre, and revealed the central part of the town plan (fig. 1; fig. 2). This field work has made possible the reconstruction of the general process of urbanisation from Hellenistic times to the late 7th c., when the large-scale occupation of Sagalassos came to an end, not long after it had been struck by a devastating earthquake. After the 7th c., the town seems to have become the locus of a *kastron*, with small-scale communities, or hamlets, existing in its central and southern parts. There is positive evidence for

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[12] See Martens (2001); Martens (2006); Martens *et al.* (in press).

[13] Waelkens (2001a).

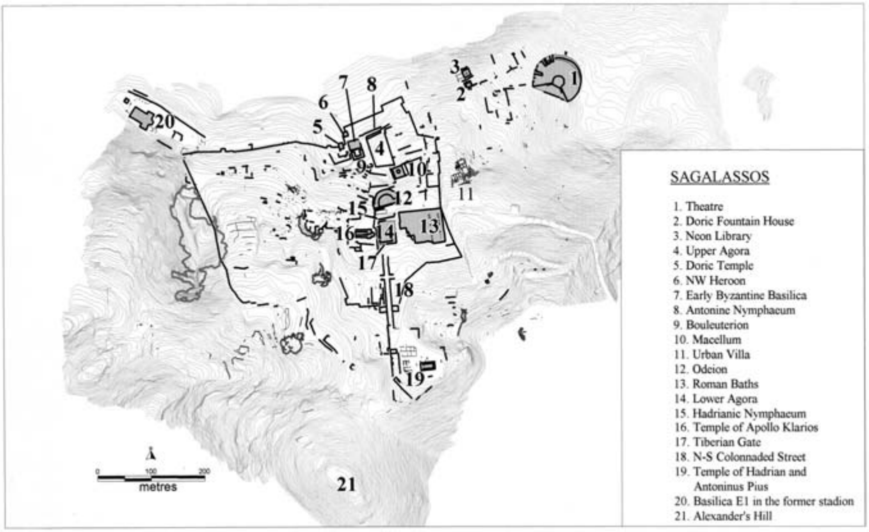

Fig. 1 Topographical map of Sagalassos.

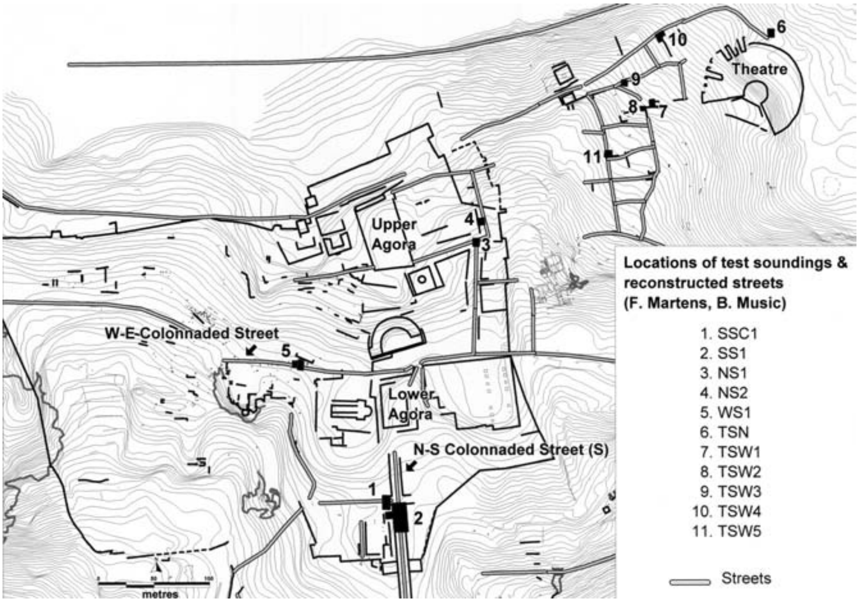

Fig. 2 Location of the street test soundings
and the tentatively reconstructed network of streets.

building activities and/or occupation in the former city centre during the 8th(?)/9th, and 10th–12th centuries; at the former Sanctuary of Apollo Klarios; and further to the south, at the former sanctuary of Hadrian and Antoninus Pius (9th/10th to 10th/11th c.), and at the fortress on Alexander's hill (late 12th–early 13th c.).

In 1998, after the initial topographical surveys,[14] a systematic investigation of the street network and related water infrastructure was initiated as part of a doctoral research project on the urban development of the town.[15] A programme of intensive archaeological survey was carried out to ascertain the development of the urban area. It included the mapping of all surface architecture.[16] Simultaneously, a series of test soundings was planned, to provide evidence of the building history and development of the urban area outside of the monumental centre. So far, between 1998 and 2005, 11 trenches have been excavated throughout the urban area (fig. 1; fig. 2), under the supervision of the author. The aim has been to gather information on the character and chronology of the layout of the urban infrastructure, and to provide feedback on the archaeological surface collection and geophysical survey, carried out at the site since 2002 by a team from Ljubljana University (Slovenia) supervised by B. Mušič (fig. 3).[17] These trenches were situated in the former western flank of the southern section of the longitudinal Colonnaded Street (1998: SSC1), and in the main arterial road and its portico (2005: SS1). Two trenches were also dug on the northern half of this North-South Colonnaded Street: at the point where it turned west to connect to the Upper Agora (1999: NS1); and 14 m further north (1999: NS2), where an offshoot of the main street continued in a northerly direction. Another two trenches were excavated on the western Colonnaded Street (1998: WS1). Further test soundings

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[14] The main streets leading into Sagalassos were first mapped by the team of K. Lanckoroński in the late 19th c., see Lanckoroński (1893). A century later, the visible remains of the southern part of the North-South Colonnaded street were mapped as part of the topographical survey of the Pisidia Project; see Waelkens *et al.* (1990) 193, fig. 6.

[15] Martens (2004). The publication of this PhD is forthcoming, as number 9 of the series, 'Studies in Eastern Mediterranean Archaeology'.

[16] Martens (2005).

[17] So far, an area of 12.5 ha has been covered using geo-magnetism, which has allowed the visualisation of the outlines of the urban plan of the eastern part of the town. Further, since 2005, geo-radar applications have also been tested at the site to trace street paving, and investigate the layout of preserved water channels.

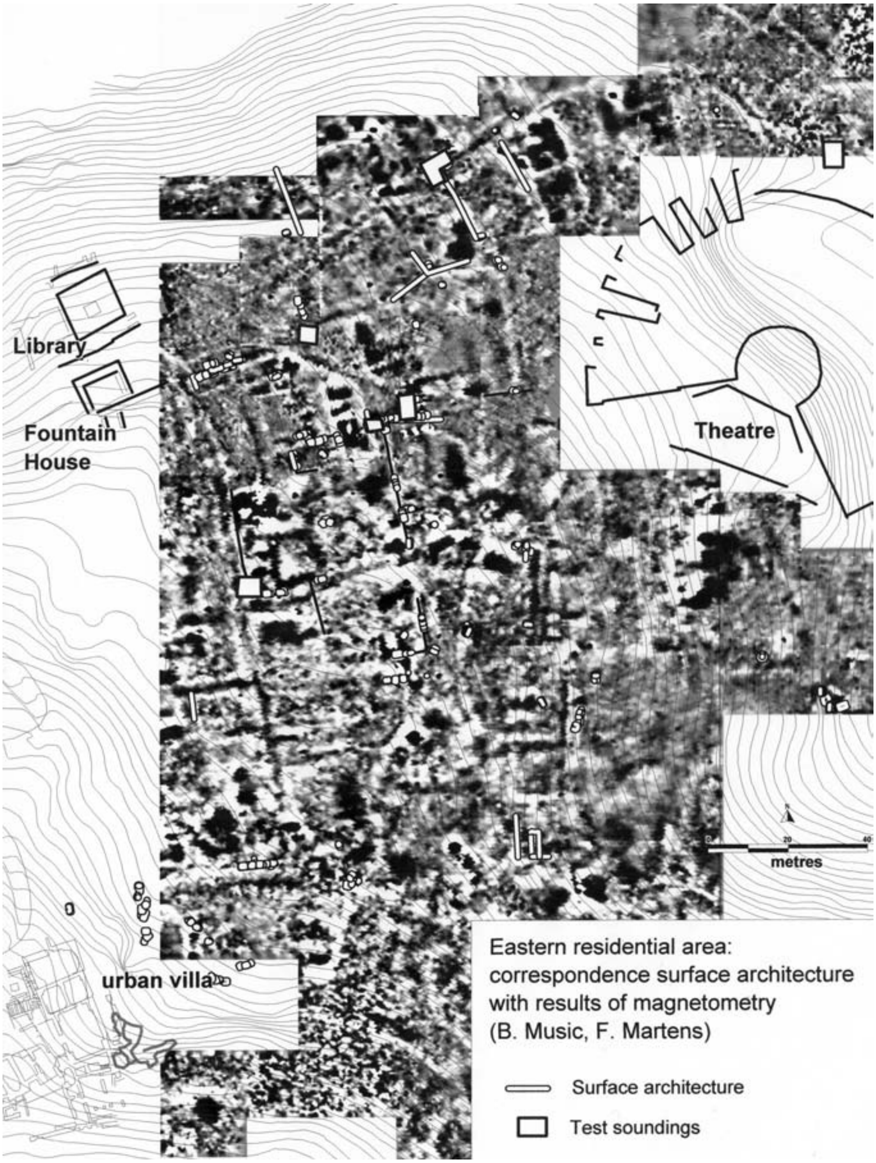
Library
Fountain House
Theatre
urban villa
0
20
40
metres
Eastern residential area: correspondence surface architecture with results of magnetometry (B. Music, F. Martens)
Surface architecture
Test soundings

Fig. 3 Results of the geophysical survey in the eastern residential area (magnetometry).

concentrated in and near the eastern residential area, with a first trench dug to the north of the Theatre (1999: TSN), and 5 other trenches excavated in the area between the Library-Fountain complex to the West and the Theatre to the East (2000: TSW 1–4; 2004: TSW5). The programme of test soundings thus yielded evidence on both main and subsidiary streets, and covered various periods. The nature of this evidence was determined by various factors, including the history of the occupation of Sagalassos, the particular terrain within which the trenches were dug and the research strategy of using test soundings, as will be explained below.

Because Sagalassos was largely abandoned after the 7th c. and never intensively inhabited thereafter, the final phase of large-scale occupation at the site is particularly well-preserved.[18] On the basis of the relative sequence of the local table ware (SRSW), this period should be dated to *ca.* A.D. 450/75–550/75,[19] a phase during which the town suffered the consequences of a destructive earthquake (in around the early 6th c.).[20] Surface finds and excavated areas are not as well documented for the subsequent period, from *ca.* A.D. 550/75 to 650. Generally, evidence from this period appears in more isolated deposits, suggesting a less extensive and less densely occupied urban landscape, possibly resulting from the impact of the mid-7th c. earthquake.[21] As opposed to the large-scale excavations of the monumental centre, the street test soundings produced no evidence dating to later than the mid-6th c.

The decision to work with test soundings has also influenced the nature of the data obtained. The programme of test soundings at Sagalassos was initially set up to localise streets and study the urban development, rather than to investigate the technology of ancient road-building as such.[22] Together with the field conditions, this explains why the actual substratum of the exposed street surfaces could only be intersected at a few places. The rugged topography, significant post-depositional surface formation processes, and erosion at the site, mean that the ancient street levels—as well as other archaeological structural evidence—are often covered with considerable amounts of debris. Consequently, the small-scale trenches, some are less than 10 m^2, frequently have to be dug deep, even though it would be safer to explore their features in such constrained circumstances at a shallower depth. Another element which should be born in mind while interpreting evidence from the test soundings is that these small-scale trenches only provide a very localised insight into the broader archaeological context. Indeed, a few metres away from the trench in question, the archaeological evidence may paint a quite different picture. It is important to consider this when extrapolating from this local evidence general processes occurring across the site. Still, test-soundings have the advantage of offering very detailed information through a minimally-invasive intervention. By combining this evidence with the results of other archaeological and geophysical research at the site, the test soundings have yielded valuable information on the evolution of the urban infrastructure at Sagalassos throughout the stages of its urban development.

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[18] This was clearly noticed in the surface record, see Martens (2005) 248, fig. 11.

[19] Poblome (1999).

[20] This earthquake was previously dated to around A.D. 518; see Waelkens *et al.* (2000b) 378. It is now believed to have struck in around A.D. 500, see Sintubin *et al.* (2003) 364.

[21] Martens (2005) 249, fig. 11; Poblome *et al.* (2005) 228.

[22] The same is true for another programme of street soundings in Asia Minor, carried out at Pergamon, Radt (1999) 83–85, 335.

The Development of the Urban Plan and the Network of Streets of Hellenistic and Imperial Sagalassos

The Hellenistic town of Sagalassos must have been rather modest in size. The town wall encompassed an area of *ca.* 12.80 ha, enclosing the monumental heart of the town with the main civic buildings, and a western residential area.[23] The monumental centre was laid out in several phases. As was typical for Hellenistic towns of this region,[24] the Upper Town was initially planned asymmetrically around the Upper Agora. A new plan, however, probably already initiated shortly after 100 B.C., brought more regularity through the re-arrangement of the Agora[25] and the construction of a number of buildings and monuments with a common orientation.[26] The first boom of monumental building work (25 B.C.–A.D. 68) also involved a programme of infrastructural activities.

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[23] Martens (2005) 245–46, fig. 12.

[24] Mitchell (1991).

[25] Waelkens *et al.* (2000a) 297–98; Waelkens (2002a) 332–33.

From the Early Imperial period, the urban area also expanded in an easterly direction, where a new residential area was laid out, and toward the South, where a second urban core was arranged around the Lower Agora in the course of the 1st and 2nd centuries A.D.[27] A monumental axis, w. 9.75 m, arranged in Tiberian times, gave access to this urban core from the South (fig. 4).[28] The edges of the expanded monumental centre were marked with monumental arches.[29] A curving street leading to the Lower Agora from the North-East was laid out on an artificially raised or re-paved level, perhaps as part of a second building boom in Trajanic times. A little later, in around the mid-2nd century. A.D., a street was inserted between the eastern portico of this lower market square and the western facade of the Roman Bath building (fig. 5). Around the same period, the elevated platform between the Hadrianic and the Trajanic Nymphaea must have been arranged and paved, an operation which also may have had implications for the West Street leading to this platform (WS1 trenches). The arrangement of these water-consuming buildings obviously must have affected the existing street system, as happened in the Upper Town around the time of the construction of the Antonine Nymphaeum (see below).[30]

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[26] The prevailing orientation of this plan of the Upper Town was on a longitudinal axis, 18°/–19°, and on a latitudinal axis, *ca.* 72°/73°, see Martens (2004) 555–58, For the Late Hellenistic and Early Imperial building history at Sagalassos, see Waelkens (2000a) and (2002b).

[27] Waelkens (2002b).

[28] The excavation of the southern half of this North-South Colonnaded Street and the adjoining western portico and shops was initiated in 2005 by F. Martens and is currently being continued under the supervision of I. Jacobs, who is also excavating the shops. The layout of this street was succeded by the construction of at least one western walkway and shops, which may be dated from the reign of Augustus onward. The street must have been one of the earliest examples of this type in the region, see Martens (2004) 461–63.

[29] In the Upper Town, arches were built at the south-eastern and south-western entrances to the Upper Agora in Julio-Claudian times, and at the north-eastern entrance of the same square in around the mid-2nd c. A.D. In the Lower Town, an arch of Augustan date probably articulated the western entrance to the monumental centre, whereas two gateways of Tiberian date marked the southern access to the main North-South Street and the southern access to the Lower Agora, see Waelkens (2002a) 341; For a summary overview of the various arches at Sagalassos with references, see Martens (2004), 591–95.

[30] Waelkens *et al.* (2000a) 239, 255, 292.

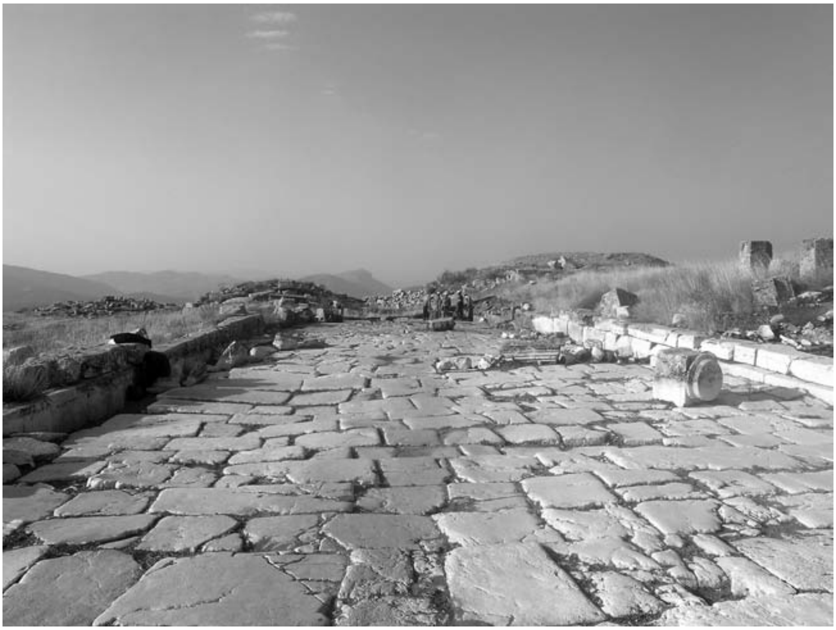

Fig. 4 View upon the southern half of
the North-South Colonnaded Street from the north.

The orientation of the buildings around the Lower Agora[31] deviated slightly from the predominant orientation of the buildings of the Upper Town (fig. 1, fig. 2). The construction of the Hadrianic Nymphaeum at the point where both sets of buildings met concealed their different alignment, which was likely to have been induced by the natural layout of the terraces upon which they stood.[32] This organisation of the town plan of Sagalassos reflected the concept of 'practical planning', which was based as far as possible on a longitudinal axis, although within the constraints posed by local topographical conditions.[33]

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[31] In a north-south direction, the prevailing orientation was *ca.* –4°; in a west-east direction it was *ca.* 84°/88°.

[32] Martens (2004) 562–63.

[33] The theory of 'practical town planning' in the towns of Asia Minor was developed by Yegül (2000), taking into account topographical features, as well as pre-existing structures. This theory is applicable to the situation at Sagalassos. For a comparable 'practical approach' in (Early) Byzantine town planning, with references, see Tsafrir and Foerster (1997) 91, 120–21.

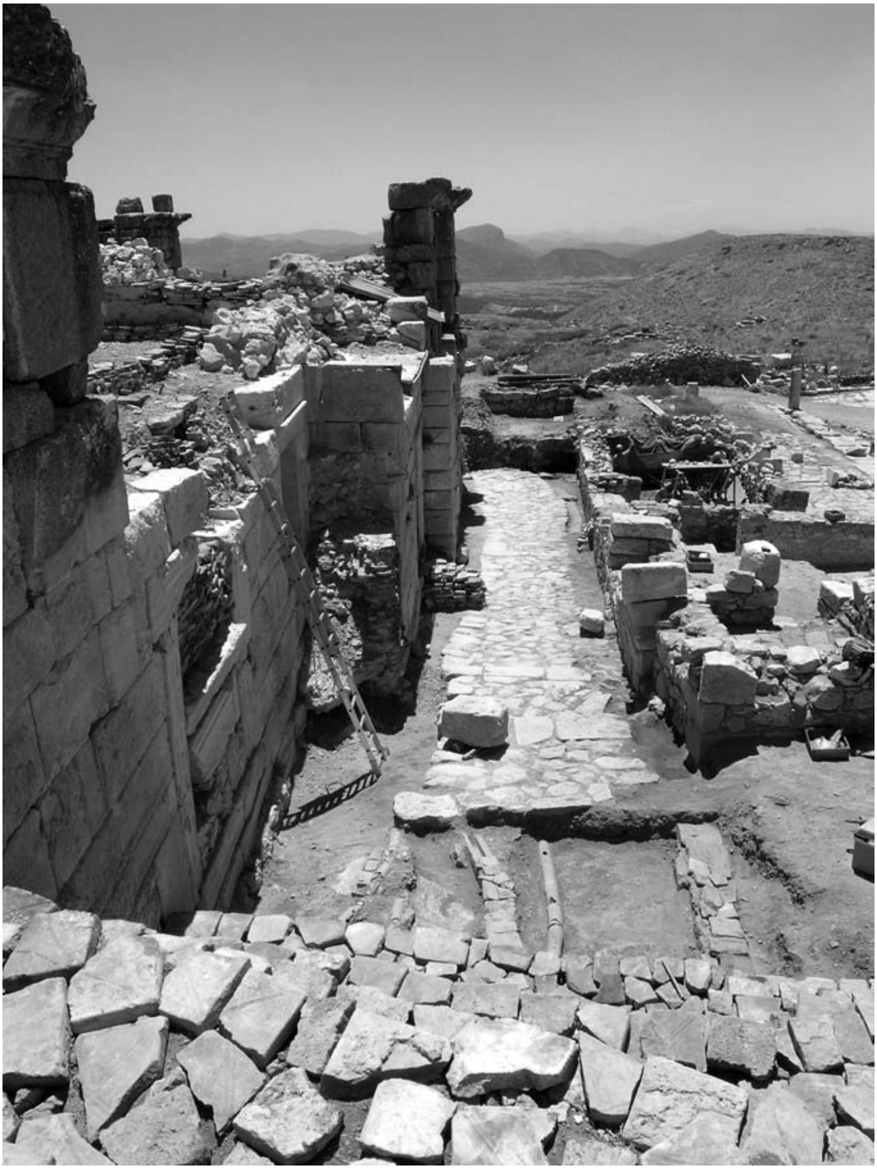

Fig. 5 View upon the street between the eastern portico of the Lower Agora and Roman Baths from the north.

The next major building programme took place during Severan times (A.D. 193–235), and must also have furthered the development of the urban infrastructure. In the monumental centre, another gateway was erected at the point where the main north-south street intersected one of the main latitudinal arteries, to the north of the Roman Baths.[34] In the eastern part of the town, however, excavations of the Library-Fountain complex and the results of 6 test soundings in the eastern residential area (fig. 1, fig. 2) suggested that a large-scale development of the urban infrastructure was carried out during the late 2nd to 3rd centuries A.D. It consisted of the arrangement of an esplanade between the Neon Library and the Doric Fountain,[35] probably in the course of the 3rd c. The street connecting the Library-Fountain complex with the Theatre to its south-west may also date to this period (fig. 3).[36] The west-east street may have been re-arranged or paved a little later, perhaps during the 3rd c. This linked the Potters' Quarter to the Library Esplanade and the Upper Town further to the west.[37]

Therefore, in the course of the first three centuries of the Imperial period, the town received all of its major buildings, and reached its maximum extent of 31.5 ha.[38] Topography played an important role in the organisation of the urban plan, both within and without the monumental centre. This was shown by the results of the geophysical survey (see below).

The Basic Features of Street Design at Sagalassos

The Substratum of the Streets

As mentioned, the *substratum* of streets could only be intersected in a few of the trenches at Sagalassos, and none of the excavated examples provided a text-book illustration of the 4-layered scheme of ancient street layout, described earlier.[39] This is, in fact, not surprising, considering that Roman road-builders never seemed to follow this scheme strictly. Indeed, excavations of Roman streets have revealed that they had different sequences of levels composed of different materials, depending on the local conditions, provenance of construction materials, and types of traffic.[40] At Sagalassos, a seemingly complete and 'undisturbed' stratigraphical sequence was excavated below the slabs of the southern half of the North-South Colonnaded Street. 4 levels were distinguished, of which the lower three formed part of an artificial fill; *ca.* th. 1.40 m, and composed of heterogeneous materials.[41] It was covered by a level containing medium to large-sized stones, and d. *ca.* 0.20 m, upon which the paving slabs of the early Imperial street had been laid (fig. 4). Apart from this example, evidence for an *in situ* paving of limestone slabs was only found in two other trenches (NS2; WS1) (fig. 6). In a third trench, upon an early Imperial street in the eastern residential area (TSW1), the archaeologists discovered a paving of cobbles embedded in beaten earth. This functioned as either a pavement of stone slabs, or a supporting layer. Generally, however, the pavements of slabs were supported by a compact level of earth, with pebbles or stone chips, and sometimes a mortar component (fig. 7).[42] The main streets of Sagalassos were probably paved with slabs

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[34] On this poorly-preserved gateway, see Vandeput (1997) 113–116; Waelkens (2002a) 356.

[35] Waelkens *et al.* (1995) 48–50.

[36] On the basis of the architectural decoration of the *scaenae frons*, the completion of the Theatre's stage is dated to the end of the 2nd c. A.D., see Vandeput (1997) 112. The *cavea* of the theatre, however, is believed to be older, see Waelkens (2002a) 355.

[37] A section through this street level was exposed in the TSW4 trench.

[38] Martens (2005) 246–48, fig. 12.

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[39] According to modern scholarly literature, the ancient street was composed of four layers: the *statumen*, the *rudus*, the *nucleus* and the *summum dorsum*. The lowest level, or *statumen,* consisted of a layer of stones, and was intended to stabilise the soil and minimise the retension of infiltrated water. The next layer, the *rudus*, was a thick watertight level of sand, or gravel, with sand, or loam. The *nucleus* was inserted upon this foundation level, which was formed by the *statumen* and *rudus*. It was a layer of variable composition that was probably intended as the 'binder' for the pavement, or the *summum dorsum*. The thickness of the substratum and pavement could average between 1 m and 1.50 m, or more, see Forbes (1965) 152; Adam (1984) 301–302; Chevallier (1997) 107–18.

[40] Forbes (1965) 152; Adam (1984) 301–302; see e.g. Chevallier (1997) 114–18, figs. 55–59. Chevallier decides "il n'existe pas de coupe-type".

[41] The fill consisted of a silty, dark-to-reddish-brown soil, with a substantial ophiolite component of greenish, reddish-brown and blackish colours, some small-sized stones, charcoal fragments and a few burned shards.

[42] See also Chevallier (1997) 116. Such levels were exposed at Sagalassos at those places where slabs had been removed (see below), including: the west-east street, north of the Upper Agora; the north-south street west of the urban villa under excavation; the northern part of the North-South Main Street (trench NS1); below the pavement of the western portico of the southern half of this street (trench SSC1); the north-eastern access to the Lower Agora; and in the west-east street traversing the eastern residential area (trench TSW4).

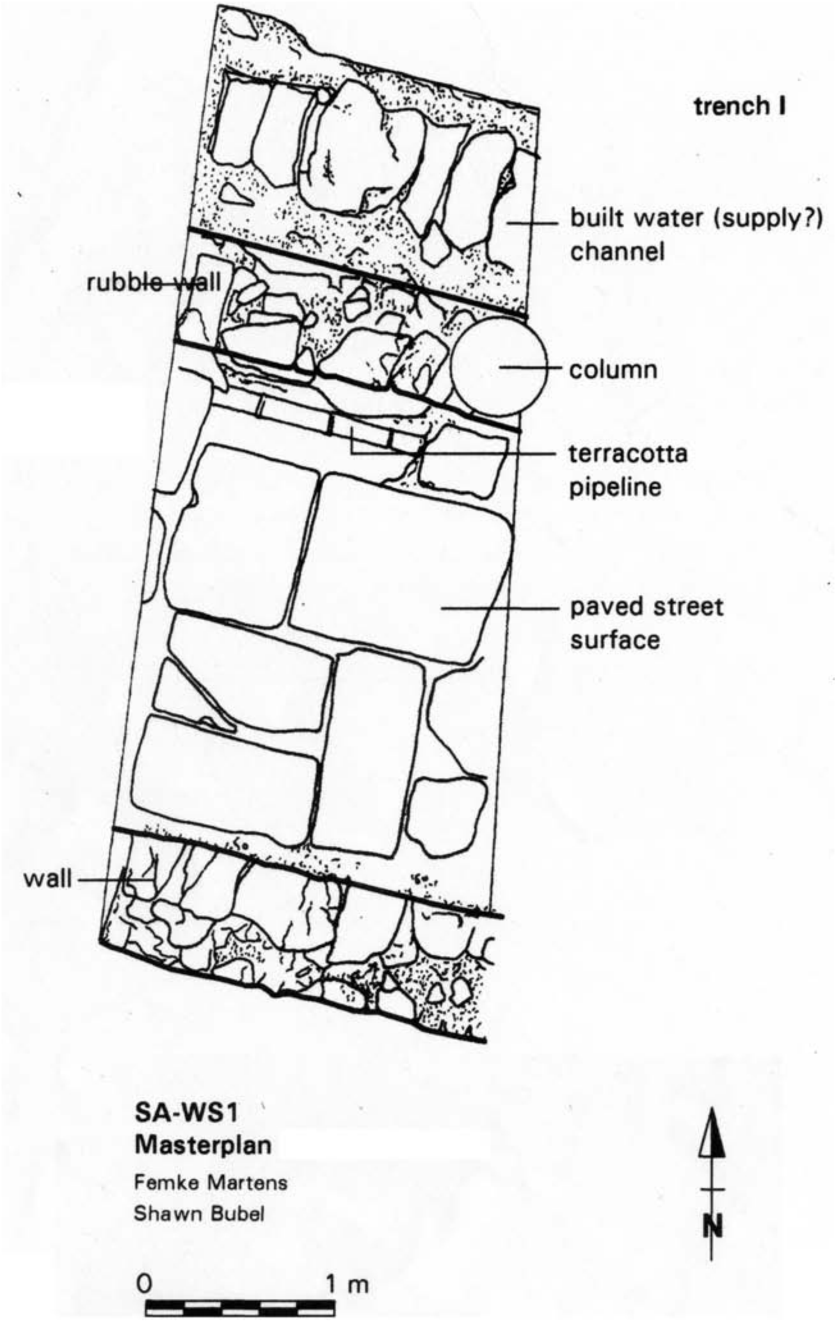

Fig. 6 Plan view of the WS1 trench (Western Colonnaded Street).

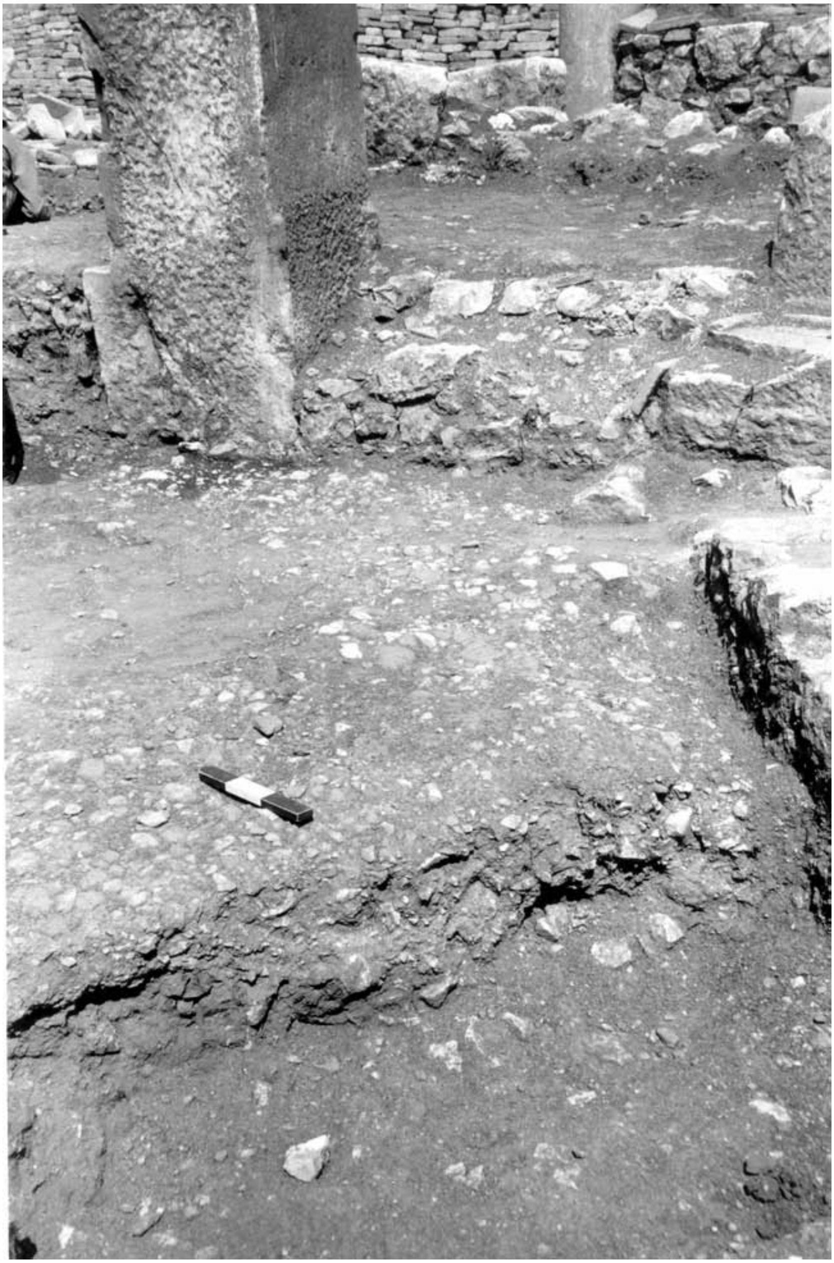

Fig. 7 View upon the stony substratum of the northeast entrance to the Lower Agora.

during the Augustan period, or the first half of the 1st c. A.D., but other secondary or minor streets may have remained unpaved until a later date. The bedrock will have been incorporated and used to carve out the street surface wherever it emerged, as is seen at other towns with a substratum of surfacing rock.[43] The majority of streets were gradually paved in the course of the Imperial period.

The Adaptation of Street Levels

Street levels were a typical feature of ancient towns that were repeatedly renovated and maintained over the years. Road repairs, or changes, frequently necessitated adaptations to adjoining buildings, to ensure that they remained accessible from the street.[44] Such re-arrangements, or repairs, occurred at Sagalassos throughout the entire history of the town, either as part of larger building programmes, or in response to earthquake damage. Sagalassos was struck by 4 known earthquakes during the period of its large-scale occupation. The first two occurred during the 1st and 3rd centuries A.D. and caused only limited damage. In contrast, the earthquakes of the early 6th and mid-7th centuries were more damaging.[45] Evidence for a first levelling operation affecting the street network was found at the TSW1 and TSW2 test soundings, upon streets in the eastern residential area (fig. 1, fig. 2). Only a few decennia after the construction of the Augustan ashlar building, along which both trenches were excavated, the area surrounding it was filled up again in order to create a new level with an additional height of at least 1.50 m. In the Upper town, the street passing to the north of the Upper Agora was also raised during the first half, or mid-2nd c., perhaps as part of the re-arrangement of the water-supply system in this part of the city, following the construction of the Antonine Nymphaeum.[46] Around the Lower Agora, the original level of the street descending toward this market square was raised in around the late 1st or early 2nd c., when the street was probably also re-paved (fig. 7).

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[43] At towns like Pergamon, the main street was paved with andesite slabs and partly cut into the bedrock, see Radt (1999) 83–84.

[44] Liebeschuetz (2001) 55.

[45] Sintubin *et al.* (2003) 364–65. Like Priene or Hierapolis, Sagalassos was situated precisely on a geological fault, which made the site vulnerable to tectonic activity, Similox-Tohon *et al.* (2004), Similox-Tohon *et al.* (2006).

[46] Waelkens *et al.* (2000a) 239, 255, 292.

As the effects of the first two earthquakes upon the network of streets were probably limited, the levelling operations may be ascribed to the different building programmes of the Julio-Claudian, Flavian/Trajanic and Hadrianic/Severan periods, when raising the street level, rather than removing the remnants of previous phases, seems to have been common practice.

Water Infrastructure

Most street soundings at Sagalassos also yielded information on the urban water-supply network. This is because the main lines of the water-supply network were often laid out simultaneously or at least in correspondence, with the street system.[47] The evidence from the excavations of this network comprised stretches of brick, or rubble, built water channels of various shapes and dimensions, terracotta water pipelines, and U-shaped terracotta channel segments, as well as various hydraulic devices. The systematic study of this evidence has allowed us to re-construct the general evolution of the layout of the water-supply network of the town.[48] Some sort of drainage system must have already existed from the early days of the urban development of Sagalassos, to evacuate rain and runoff water. Between the late 1st c. A.D. and the second half of the 2nd c. at the latest, a more elaborate water network must have been arranged given that, by this point, no less than 5 extra-urban aqueducts[49] supplied vast quantities of water to three *nymphaea,* a monumental street fountain and a Bath Building around the Lower Agora, and the *nymphaeum* and other water-consuming buildings around the Upper Agora.[50] Also private consumers were able to connect to this lavish water-supply and there can be little doubt that a proper drainage system was installed at this time to evacuate the distributed water.[51]

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[47] Hodge (1992) 340; Crouch (1993) 187; Crouch (1996); Jansen (2000) 109.

[48] Martens (2001) and (2006); Martens *et al.* (forthcoming).

[49] On the relative chronology of these aqueducts with further references, see Martens (2005) 181–82.

[50] For the chronology and building history of these constructions, with further references, see Waelkens (2002a); Martens (2006); Martens *et al.* (forthcoming); Richard (forthcoming) Mägele et al. (2007).

[51] Drainage outlets arranged along the western edge of the Lower Agora also suggested that the increase of surface drainage following the urbanisation of the site was provided for, see Martens (2001) 65, n.79, fig. 10.; and (2005) 182, n.28.

Although the network's imperial distribution points have not yet been identified, the morphology of the channels and the functional context allowed to distinguish between main and secondary water-supply channels, and the various types of drainage channels and sewers.[52] The position of the main water channels below the streets was well-illustrated by the TSW4 trench, dug upon an important latitudinal axis in the eastern residential area (fig. 8). The different modes of construction of the underlying water channels suggest that the southernmost channel, running below the southern edge of the street, was a supply channel.[53] Conversely, the northernmost channel that ran 1.20 m further north, was clearly a drain,[54] which may originally have run centrally (?) below the originally wider street (see below) (fig. 8). The arrangement of (main) supply and drainage channels below streets was logical, as this meant they were easily accessible for maintenance work.[55] There is no solid evidence regarding the position of drainage systems, either at the edges or below the streets. Further, the fact that evidence from other towns shows a variety of arrangements makes it impossible to hypothesise.[56]

Street Widths

As in other towns, the width of streets at Sagalassos must have varied according to their importance. Our best information concerns the main streets and their arteries, which generally ranged between 5 and 6.70 m

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[52] In particular, the presence of an interior mortar coating proved to be a valid criterion for distinguishing supply from drainage channels, see Martens (2006) 166; Martens *et al.* (forthcoming).

[53] The channel had a roughly trapezoidal section with an interior width of 30 cm and an interior height of between 77 and 118 cm. The channel was covered with large rubble blocks, which were mortared together. The conduit proper possessed a tiled floor, and its walls, w. 35 cm, were composed of mortared rubble. Inside the conduit, the walls were first coated with grey construction mortar (3 cm), finished with a finer layer of pink hydraulic mortar (0.9 cm). The careful construction and applied mortar coating of the conduit suggested that it was related to the water supply system.

[54] This vaulted channel ran at a deeper level, and was partly filled with sediments. The measurable interior width was 60 cm, while the minimum interior height upon the sediment was 85 cm. A terracotta water pipe supplied the channel, suggesting that it collected water. This fact, the absence of an interior mortar coating, and the contrast with the 'supply channel', suggested that it functioned as a drainage channel.

[55] Street soundings at Pergamon suggested that alterations to the water network below the streets must have frequently hindered traffic, see Radt (1999) 85.

[56] For colonnaded streets, see e.g. Segal (1997) 51; for a brief overview of various arrangements, see Martens (2004) 435.

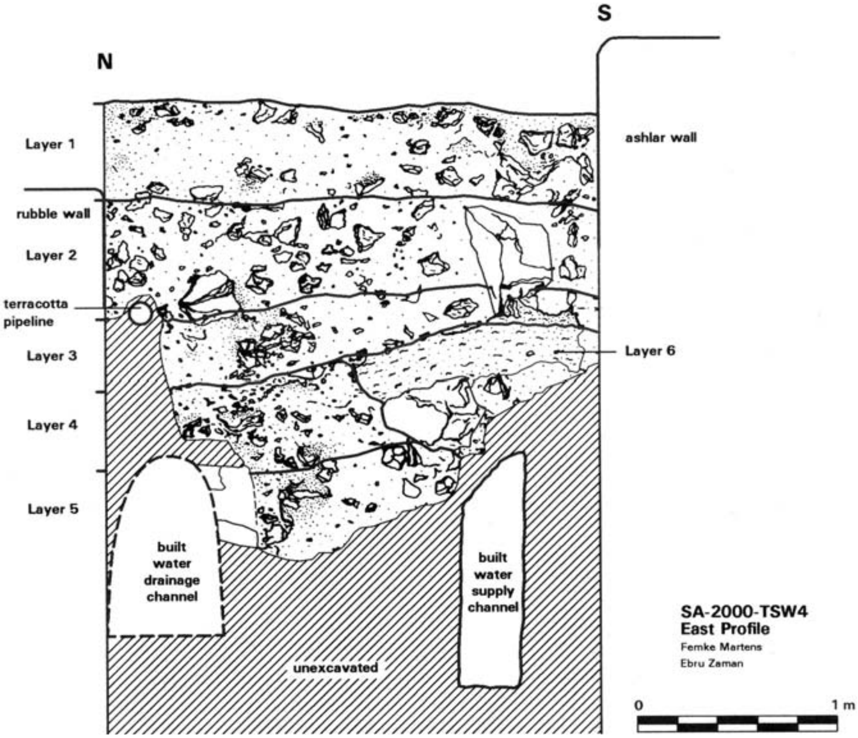

Fig. 8 East Profile of the TSW4 test sounding (eastern residential area).

wide. This corresponded with evidence from other cities in Asia Minor. The wider North-South Colonnaded Street (fig. 4) is an exception.[57] The estimated widths of secondary streets, such as those in the residential quarters, were between 2 and 4 m.[58] Alleys were not excavated at Sagalassos, but were probably comparable, in width and appearance, to those found in other mountainous sites like Pergamon, where (stepped) alleys were, at the most, w. 1.40 m.[59] In addition, excavations at Sagalassos also yielded evidence for streets that had apparently been narrowed in Late Antiquity. This was suggested by stratigraphical evidence and the position of the underlying water infrastructure which, for some streets, still gave an indication of their original width.

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[57] The exposed southern part of this street was 9.75 m, with an additional western sidewalk of *ca.* 3.50 m. Further north, at the point where it reached the Upper Agora, the street became exceptionally wide, at 14 to 15.80 m. For the widths of other colonnaded streets, see Bejor (1999).

[58] These widths were deduced from the results of the geophysical survey and test soundings.

[59] Radt (1978) 11.

Wheeled Traffic

Cart transport at mountainous sites like Sagalassos could be impeded by both the narrow width of the streets, and topographical factors. The maximum inclinations of modern streets are between 7 and 9%.[60] In ancient towns, however, much steeper streets were also found,[61] although slopes of 15% are considered to be the absolutely steepest that carts or carriages could negotiate in this period.[62] Most slopes at Sagalassos currently exceed the standard of 7% for comfortable wheeled traffic, and this situation must have been comparable in antiquity, when they had not yet been covered with eroded sediments. So far, no wheel ruts have been discovered on the street paving of Sagalassos, although this does not necessarily imply that the city did not accommodate wheeled traffic, as will be asserted below. Clearly, many of the longitudinal arteries must have been off limits to carts or carriages, given that they were stepped, or were on such steep inclines that they contained staircases.[63] The layout of the urban plan of Sagalassos, however, seems to have taken these topographical conditions into account. Streets were organised either perpendicularly to the slope, thus assisting the distribution and drainage of water, or largely followed the contours of the landscape, which allowed wheeled traffic to frequent at least some parts of the main latitudinal axes (fig. 1, fig. 2).[64] Although carts or sledges could have circulated (parts of) the principal axes of the city, these remained hard to reach by the steeply-sloping roads approaching the town from the valley below.

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[60] Chevallier (1997) 108.

[61] Many streets at Athens or Priene intended for wheeled traffic had inclinations of 10% to 15%, see Martin (1974) 208. At Ephesus, the 'Kuretes Street', which also served vehicular traffic, had a gradient of 10%, see Scherrer (2000) 114.

[62] Chevallier (1997) 108.

[63] This is clearly visible at the lower half of the North-South Colonnaded street, see Waelkens *et al.* (1990) 193. At towns like Priene, streets with inclinations of 30% to 45% have been mapped, which were, by necessity, stepped, and thus only accessible to pack-animals, see Martin (1974) 114.

[64] This was deduced from an analysis of the inclinations of known streets, see Martens (2004) 442–44. The same practical logic in town planning was also noticed in other ancient towns. For nearby Cremna, see Owens in Mitchell *et al.* (1995) 160; for Constantinople, see Berger (2000) 163.

The Condition of the Street Network of Sagalassos in Late Antiquity

The urban fabric of Sagalassos underwent considerable changes in Late Antiquity, whether or not this was related to the much debated 'decay of the Classical city'.[65] The evolution of its street network and urban infrastructure at large should be interpreted against the background of these general issues of maintenance. For this reason, it will now be necessary to summarise the evolution of the physical condition of the urban fabric from the 4th c., paying particular attention to the development of the water network,[66] and taking into account a number of influential internal and external factors.

The General Maintenance of the Urban Fabric from Late Imperial (A.D. 300 until A.D. 450/75) to Early Byzantine Times (A.D. 450/75–A.D. 640/50)

After the prosperity of the preceding centuries, Late Imperial Sagalassos was generally characterised by sustained prosperity. The survey results suggested that it retained the same urban area and was still densely occupied.[67] Where architecture is concerned, there were no more grand building projects, but the existing public buildings were well-maintained. The Library and Baths were modified, or re-decorated, part of the Antonine Nymphaeum and terrace building north of the Upper Agora were repaired, and there were also structural alterations in the area of the Lower Agora.[68] The only new monumental constructions were

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[65] Symptoms of urban decay according to the general appearance of the late antique city are described by, among others, Russell (1986) 144; Saradi-Mendelovici (1988) 370; Ward-Perkins (1988) 16–19; Cameron (1993) 159–162; Haldon (1999) 4 and Liebeschuetz (2001) 30–43.

[66] The water network of Sagalassos has been investigated at the same time as the network of streets, but—as mentioned—the results of this enquiry have already been published extensively in other contributions and will only be summarised here.

[67] Martens (2005) 248.

[68] Vanhaverbeke *et al.* (2004) 251; Waelkens *et al.* (2006) 218–20.

Churches, and these were entirely built of *spolia*. They were erected as a result of the increasing Christianisation of the population of Sagalassos, which affected the urban landscape from the early 5th c.[69] Politically, the 5th c. witnessed the decline of the city council, and the emergence of local ruling elites comprising church leaders, principal landowners and an assortment of prominent citizens.[70]

The general stability of the Late Imperial period was interrupted around the turn of the 5th c. by internal rioting, which was possibly responsible for the destruction of the Neon Library,[71] as well as by external threats posed by the Isaurians, who ravaged Pisidia between A.D. 404 and A.D. 406.[72] This military insecurity probably incited the construction of a new fortification wall, built of *spolia* in around A.D. 400. The layout of this wall, which excluded the Doric Fountain House (fig. 1, fig. 2), must have influenced the organisation of the water network within the walled circuit. In particular, arrangements were made for a more economical use of water in emergency situations in the north-western part of the walled area, around the North-West Heroon.[73]

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[69] Waelkens *et al.* (2006) 224.

[70] Waelkens *et al.* (2000a) 260–67; Waelkens *et al.* (2006) 226, There is no direct evidence from Sagalassos on the authorities responsible for the supervision and maintenance of its public infrastructure. The evidence from other towns shows a variety of arrangements over time. For an overview with references, see Martens (2004) 416–422. On the authorities responsible for the maintenance of buildings and public infrastructure in the East in Late Antiquity, see Di Segni (1995), with respect to the maintenance of the water infrastructure, either on public or private initiative, see also Eck (1987) and Di Segni (2002). For an example of the personal involvement of town dwellers in Late Antiquity, see Liebeschuetz (2000).

[71] Further to the East, the gymnasium, symbol of the old Greek 'paideia', or education (see Waelkens *et al.* (2000c) 435–36), was also systematically dismantled in the late 4th c., possibly with 'official' consent.

[72] Belke and Mersich (1990) 79–80.

[73] Probably in the early 5th c., a vaulted reservoir (exterior dimensions of 2.40 × 1.60 m) was built between the North-West Heroon and the Late Fortification Wall, see Waelkens *et al.* (2000d) 560, fig. 17. The reservoir resembled the ones found at Ostia (see Jansen (2002) 139–146, figs. IV.29,31,33), and served here as the collection point of an intermittent flow of water originating from melting snow, or ice, see Martens (2001) 69, n.103. At the same time, on the eastern side of the North-West Heroon, an installation collected rainwater from the upper part of the fortifications, or the from the Heroon, using a large terracotta tile (73 × 73 cm) and an associated man-made water channel, see Waelkens *et al.* (2000d) 561, fig. 19. At some point during Late Antiquity, a rock-cut cistern was arranged to the east of the Heroon, although this system may also have been constructed at the same time as the layout of a 6th c. fountain here, see Martens (2004) 534, 538–39.

Although the late antique fortification wall only enclosed the monumental heart of the town and part of the western residential area, the extra-mural urban area remained inhabited until at least the mid-6th c.[74]

Despite these temporal signs of internal and external pressure, the town still prospered long into the 6th c. The scale and monumentality of the renovation of public buildings and infrastructure after the devastating earthquake of the early 6th c. suggests that the town was still efficiently governed by prosperous ruling authorities.[75] The Roman Baths were extensively repaired and modified, most of the porticoes, public fountains and *nymphaea* were repaired, or adapted, and the southern entrance to the Lower Agora was embellished with a new monumental staircase and a re-constructed gateway.[76] On the other hand, the encroachment upon former public spaces, which had began in the early 5th c., seems to have gathered pace during this period, although the phenomenon may have been related to commercial changes, rather than being an obvious sign of 'decline'.[77]

There was also still clearly a concern for public sanitation, as is illustrated by evidence for the establishment of a public latrine on the ground floor of the Roman Baths in the course of the 6th c.[78] Human waste was expelled from this latrine through a large sewage system,[79] demonstrating that the main lines of the network continued to function and were well-maintained.[80] Nonetheless, the early 6th c. earthquake must have caused considerable damage to the urban infrastructure. The study of the water network showed that a number of 6th c. water distribution points continued to function within the town. The Late Hellenistic Doric Fountain House was no longer used as a public fountain, but functioned instead as a kind of secondary *Castellum* for water distribution.[81] A second distribution point was located immediately west of the North-West Heroon, where the arrangements of the early 5th c. were maintained and water was also still distributed from the Antonine Nymphaeum.

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[74] Martens (2004) vol. I; and (2005) 248–49. The large-scale public construction of this wall should be interpreted as an expression of vigorous civic pride in the town, rather than as a sign of 'decline'.

[75] Waelkens *et al.* (2006) 231, on the scale of the damage caused by this earthquake, see Waelkens *et al.* (2000b), Sintubin *et al.* (2003).

[76] Vanhaverbeke *et al.* (2004) 252, Vanhaverbeke *et al.* (forthcoming), on the Tiberian Gateway of the Lower Agora, see below.

[77] Waelkens *et al.* (2006) 229–31, 234–35, 248.

[78] This public latrine, with dimensions of *ca.* 8 × 10.50 m, may have had a seating capacity of *ca.* 60; see Waelkens (2001b) 172, fig. 10; Martens (2001) 67, fig. 12; Martens *et al.* (forthcoming).

[79] This rubble-built channel, which must have already been in use since the 2nd c. A.D. at least, was partly vaulted, and partly covered with slabs, with an average height of 1.22 m, an average width of 0.83 m and a slope of 13°. The floor of the channel was made of large cobbled stones, and was fed by multiple smaller channels from the East and the West. The system was detected to the West of the Roman Baths, and was investigated and mapped in 1998 by S. Bubel and E. Erb. For a summary of this report, to be published in 'Sagalassos VI', see Martens (2004) 503–507.

[80] Martens (2001) 70–71, n.113; Martens *et al.* (forthcoming).

In addition to these developments, there is also clear evidence for the disturbance, or reduction, of the natural water supply at this time. This may also have resulted from the earthquake, which conceivably damaged aqueducts and may have closed some springs.[82] This is suggested by the apparently increased importance to the urban water management system of melting snow and rain water, and the appearance of cisterns in the urban landscape.[83] Further, new outlets, cut at a much lower level in the parapets of the basins of the Antonine Nymphaeum on the Upper Agora, and the Severan Nymphaeum on the Lower Agora, seem to confirm that the once lavishly-supplied town was now experiencing water shortages. Nevertheless, a number of the water-collecting structures that were supplied by rain water were still monumental in appearance.[84] Water-consuming buildings such as the Roman Baths remained—at least partially—in use until the later 6th, and probably even into the 7th c., which suggests that the water shortages were not very serious.[85]

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[81] The former courtyard of this building was filled up during the first half of the 6th c. to support terracotta pipelines, tapping water directly from the feeding chamber of the former fountain, and carrying it to the lower-lying urban quarters. At the same time, a channel leading from a settling tank behind the back wall of the former fountain also carried water in the direction of the Upper Agora, see Waelkens *et al.* (1997) 110–14 and (2000a) 324–29, Martens *et al.* (forthcoming).

[82] Similox-Tohon *et al.* (2006) 377.

[83] Martens (2001) 68–71; (2004) 546–48 and (2006) 183.

[84] This was the case with a large open-air basin built along western edge of the Upper Agora in front of the west portico (Waelkens (2002c) 12, fig. 2), and with the double fountain located immediately to the east of the North-West Heroon, the interior of which was covered with different types of coloured marble, see Waelkens *et al.* (2000d) 567–68, fig. 28–29.

[85] Martens (2006) 183; Martens *et al.* (forthcoming).

A number of factors seem to have led to a reversal of the town's fortunes during the second half of the 6th c. After the internal political changes and rise of Christianity had already transformed the 'classical' appearance of the town during the 5th and early 6th centuries, increasing aridity, plague, external military threats, the decline of long distance trade, and general insecurity caused by brigandage and revolts, must have further weakened the town.[86] After the middle of the 6th c., no more buildings were erected. Former mansions were subdivided and lost their grandeur, while 'rural' structures proliferated within intra-mural areas.[87] Parts of the public water distribution and sewage networks, which seemed to have been well-maintained up until this point, were abandoned. Consequently, the expulsion and disposal of waste seem to have become problematic, suggesting that there no longer existed a civic government capable of these tasks.[88] The construction of some rudimentary cisterns suggests that water shortages may have become more pressing during this final phase of the large-scale occupation of the town.[89]

The extent and density of the occupation of the town after the mid-6th c. are difficult to measure, as there are very few surface remains datable to this period, possibly because they were not re-worked or spread over the surface during later periods of intensive occupation. The available evidence, however, seems to suggest a significantly less widespread and, perhaps, also less dense occupation during this period, although further research is required to shed more light upon this final phase of the large-scale occupation at Sagalassos.[90] Finally, the weakened town was struck by a devastating earthquake in around the mid-7th c.,[91] from which it could not recover and, sometime after this event, Sagalassos must have been largely abandoned,[92] destined to become the locus of a 'kastron' (see above).

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[86] Vanhaverbeke *et al.* (2004), Vanhaverbeke *et al.* (forthcoming), Waelkens *et al.* (2006) 247–48.

[87] Waelkens *et al.* (2006) 233–35.

[88] Waelkens *et al.* (2006) 235. Some striking examples include: the large water basin west of the Upper Agora; and the Trajanic Street Fountain to the North-East of the Lower Agora, which became dumps; and the public latrine below the Roman Baths, which was transformed into a collection point for human waste, probably destined to be used as agricultural fertiliser, see Waelkens *et al.* (2006) 233.

[89] Martens (2004) 534–36.

[90] Martens (2005) 249, Waelkens *et al.* (2006) 231–32.

[91] Sintubin *et al.* (2003) 365, 372.

The Maintenance of the Street System

Although the ancient sources make little reference to the constant repairs that were necessary to keep the public amenities of a city in an acceptable condition,[93] it is clear that streets cannot have remained in use without continuous maintenance.[94] The late antique evidence from the large-scale excavations and test soundings at Sagalassos shows different types of maintenance work, including the alteration and, sometimes, abandonment of street surfaces. Whether or not the urban infrastructure was maintained plays a key role in the debate regarding whether the late antique city changed or declined. Much of the archaeological evidence can be interpreted in different ways, depending on one's perspective. Therefore, scholars have argued that a corpus of accessible and well-dated basic evidence will be fundamental to determining the nature of the evolution of the late antique city.[95] The evidence for the maintenance of the street network of Sagalassos—so far largely unpublished—is still rather limited, but does show some trends, as will be demonstrated below.

Positive Indications of Maintenance Work—Newly-Constructed Staircases

In addition to streets, at least two monumental staircases were re-built during the Early Byzantine period, presumably after the early 6th c. earthquake. The Tiberian Gateway, which marked the southern entrance to the Lower Agora, collapsed during the natural calamity. While this monumental arch was subsequently re-built as a three-column monument, many of its remains were incorporated as steps by the preceding monumental staircase, also re-built during the 6th c.[96] In its 6th c. phase, this monumental staircase of 21 steps had a maximum width of *ca.* 10.40 m, a total height of between 4.81 and 5.01 m, and covered a distance of 20 m up to the Agora. A landing divided a lower series of stairs from an additional stairway of only 6 steps leading to the Agora.[97]

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[92] Compare also with the different response to two subsequent earthquakes at Sycthopolis, Tsafir and Foerster (1997) 112–14, 143–44. Whereas the restoration of Sagalassos after the early 6th c. earthquake may have represented a challenge to which the civic authorities responded with a monumental re-building program, a combination of factors—including the (partial?) disruption of the local water supply—ruled out such a vigorous response when the town was hit again during the 7th century.

[93] Vann (1982) 165.

[94] Laurence (2004) 44.

[95] Cameron (1993) 163–64; Liebeschuetz (2001) 29.

In the Upper Town, the whole portico complex west of the Upper Agora underwent a major reorganization between the late 5th and mid-6th century, which involved the construction of a w. *ca.* 9 m monumental staircase, dividing the complex into northern and southern parts. This staircase gave access to the open atrium of the Christian Basilica, formed by the remains of the former Council Hall, from the Upper Agora to the east.[98]

Positive Indications of Maintenance Work—Newly-Arranged and Narrowed Streets

In the Upper Town, the original Early Hellenistic street,[99] which gives access to the Upper Agora from the North-East, had already been narrowed once during the Early Imperial period, following the construction of the so-called 'Northeast Building' south of the road. This made the street wedge-shaped and reduced its width from 4.60–4.87 m to 3.90 m.[100] During the Late Roman/Early Byzantine period, the street was further narrowed to a width of 2.90 m through the construction of a wall on the northern face of the 'Northeast Building'.[101] This operation also involved the re-arrangement of the pre-existing water infrastructure below the street. The fill into which the drainage channel was dug below this street can be dated to between the mid-5th and mid-6th centuries, perhaps after the early 6th c. earthquake. The fact that the conduit was constructed with *spolia* also points to a date in Late Antiquity.[102]

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[96] Waelkens *et al.* (1997) 208–10, figs. 173–74; Waelkens *et al.* (2000a) 362–67, figs. 187–88.

[97] Waelkens *et al.* (2000a) 367, see also Martens (2001) 65, n.79, fig. 10 and (2005) 182, n.28.

[98] Talloen *et al.* (2001) 162–63.

[99] The street must have been arranged during the Early Hellenistic period, when a market building was built to the north, see Waelkens *et al.* (2000a) 303–304.

[100] Waelkens *et al.* (2000a) 311. During the second half of the 2nd c. A.D., an arched gate was built between the remaining part of the Market Building and the 'Northeast Building'.

[101] Waelkens *et al.* (2000a) 311.

In Late Antiquity, the Colonnaded Street of the Lower Town, which provided access to the Lower Agora from the West, was re-furbished. Although it became narrower, it was monumentalised. This process, revealed by two WS1 trenches dug in this street, could also be dated to the period 450/75–550/75 (fig. 6).[103] The newly-laid street surface of limestone slabs was reinforced at both edges by mortared rubble walls. A carefully constructed water channel was found running along this traffic axis in the direction of the Lower Agora. It was located beside and about 0.70 m below the top level of the northern bounding wall.[104] Between A.D. 450/75 and 550/75, a th. 65 to 70 cm fill covered this water channel and the area north of the paved street surface. This fill reached the level of the bounding walls of the street surface. The top level of the wall bounding the pavement to the north served as the platform for a series of re-used columns.[105] Throughout this late antique building phase, the entire street was still furnished with columns, of which 23 examples—most of them collapsed—[106] were found *in situ*. It would appear that the water-supply system was originally positioned (centrally?) beneath the street which must, therefore, have been narrowed to its current width of only 2.50 m. This is suggested by the position of the water channel; alongside, instead of below, the paved surface, as well as the carefully constructed conduit, sealed on its outside with a mortar capping.

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[102] The channel with a rectangular section had an interior width of between 45 and 62 cm, and an interior height of between 55 and 92 cm. Its walls were constructed of mortared rubble with large, quite regular, field boulders, without a mortar coating. The floor of the channel consisted largely of the natural ophiolitic subsoil, although some slabs and rubble blocks also seemed to have been inserted.

[103] For a report of this excavation, see Martens (2004) 227–28, 427, 453–54.

[104] This conduit had a rectangular section and interior dimensions of 85 × 40 cm. It was covered by large rubble blocks, mortared together into a solid construction. The channel's walls were constructed with masonry of mortared rubble with brick, and had been lightly smoothened with grey construction mortar, although the masonry of the walls was not entirely concealed. The tile floor of the conduit was also lined at the sides with grey construction mortar.

[105] The different diameters and styles of these columns clearly show that they were re-used elements.

[106] The solid construction of this street, with abutting walls, as well as the visible damage which occurred after its Late Roman refurbishment, may indicate that this area was liable to the phenomenon of slumping, perhaps triggered by tectonic activity in this case.

This re-arrangement of the western colonnaded street has been dated to between A.D. 450/75 and 550/75, which suggests that it may well have been prompted by the early 6th c. earthquake. On the other hand, the second WS1 trench, excavated 3 m to the west, showed a different situation: of a street that had been partly abandoned not long after it had been monumentalised. Between the mid-5th and mid-6th centuries, the pavement of the street was (partially) removed, exposing in this second trench a vaulted, un-identifiable structure, bounded by walls of mortared rubble.

The phenomenon of narrowing streets in late antique Sagalassos also affected the west-east axis investigated in the TSW4 trench (fig. 2),[107] which linked the Potters' Quarter to the east, with the Library esplanade and Upper Town to the west. The robbing of stone slabs in Late Antiquity would explain why no actual paved surface has been found in this trench. In spite of this, the presence and position of the water channels in relation to the architectural context suggest that the original street must have been narrowed at some point.[108] Part of the substratum of the former street was preserved between the ashlar wall of a 3rd c. building to the south, and a late antique wall of mortared rubble to the north. Below this late 2nd to 3rd c. compact stony level (fig. 8: layer 6), a U-shaped water supply channel was exposed, running along the edge of the adjoining ashlar building and parallel with a vaulted drainage channel that had been installed 1.20 m further north.[109] In Late Antiquity, the substratum of this street was disrupted, perhaps by maintenance works on the underlying water channels, after which both were covered again with a *ca.* th. 1 m fill.[110] The filling layers (fig. 8: layers 4 and 5) were covered by a level (fig. 8: layer 3) of material relating to the construction of a mortared rubble wall and parallel water pipe. These seem to have been laid on an exposed (walking?) surface at some point during Late Antiquity, perhaps in the 6th c.[111] Based on the position of the drainage channel; below the newly-built mortared rubble wall, the latter seems to have been constructed in order to narrow the street to 2.50 m (it may originally have been double that). This operation must have been carried out during Late Antiquity, between the mid-5th and mid-6th centuries. Some time after this operation, the paving slabs of this street were removed. The street finally lost its function when it was encroached upon by an Early Byzantine rubble-built mortared construction which covered the street and blocked the thoroughfare.

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[107] For a report of this excavation, see Martens (2004) 191–93, 436, 452–53.

[108] The removal of slabs and narrowing of the street are processes that have been detected from the excavated archaeological context. There is no objective evidence for these activities.

[109] The properties of these conduits have been discussed above, under the heading 'Water Infrastructure'.

[110] Such an operation would also explain the mixed pottery contents of this filling level, which date to between the late 2nd and 3rd centuries A.D. and the 6th c.

[111] The pottery contents of this level were again mixed with both middle Imperial, and late antique pottery dating to the 6th c. The interpretation that this level was an exposed walking surface during Late Antiquity was deduced from the fact that the

Although no wheel ruts were found in the preserved street pavements, it seems significant that the width of the re-arranged streets respected the basic dimensions of 2.40 m, or 8 roman feet, which is the minimum width required for wheeled traffic moving in one direction.[112] Apart from the examples described thus far, this basic width seems to have been respected in at least two other places at the site: the early 5th c. north-west city gate;[113] and the narrow street between the east portico of the Lower Agora and the Roman baths (see also the discussion below) (fig. 5).[114]

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terracotta pipeline was completely sealed with mortar, which is unusual, whereas traces of a pink hydraulic mortar coating were found, over the full volume of the over-lying level 2, on the lateral walls framing the street.

[112] A text by Hyginus refers to an edict of Augustus, prescribing standard widths of centuriated land, including 8 feet (2.40 m) for minor streets , see Hyginus *De limitibus constituendis* 111. 9–15; 194. 9–13; *Liber coloniarum* I 211.21–212.7. Based on the evidence from Pompeii, the minimal street width for wheeled traffic in antique towns can be calculated by combining the evidence of ruts with the wheel span and total width of a preserved carriage, see Tsujimura (1991). Based on an average width of 1.40 m for Roman wheel ruts, and counting a space of at least *ca.* 0.20 m on either side of the carriage for the protruding hubs of the wheels, about 0.30 m on either side of the carriage would still be free, even for the upper part of the carriage in a w. 2.40 m street. The street width of 8 feet, as referred to by Hyginus, can therefore be considered as a minimum width for one-way wheeled traffic, see van Binnebeke (1997) 24. For two-way traffic, Tsujimura calculated a minimum street width of between 3.21 and 3.53 m, depending on the dimensions of the cart, see Tsujimura (1991) 61–63. For a new approach to this research, see Poehler (2006).

[113] This thoroughfare was arranged with a small step of *ca.* 5 cm, which would have to be overcome, see Loots *et al.* (2000) 620, fig. 27; Waelkens *et al.* (2000) 231, figs. 15–16. The corresponding street north of the Upper Agora, the level of which was raised after the early 6th c. earthquake (see below), was only partly preserved, so that its width could not be established.

[114] The paved section of this originally mid-Imperial street was between w. 2.05 and 2.60 m, but the wall-to-wall distance between the portico and the Roman Baths was a minimum of 3 m, allowing traffic through if manoeuvred carefully.

Positive Indications of Maintenance Work—Levelling Operations

Levelling operations are attested throughout the entire period of the occupation at Sagalassos and must have been a common occurrence during street construction works (see above). In Late Antiquity, however, especially following the early 6th or mid-7th c. earthquakes, the raising of street levels seems to have become more common than the abandonment of surfaces covered with debris. This may be a significant indication that the city's urban fabric was being maintained. Between the 6th and the first half of the 7th c., the paved street passing to the north of the Upper Agora was raised once more, with a considerable fill, th. 0.70 to 1.75 m.[115] Assuming that this repair was carried out in response to earthquake damage, it is striking that it had taken several decades to restore the street.[116] In the Lower Town, the pavement of the street between the eastern portico of the Lower Agora and the western facade of the Roman Baths had been repaired on various occasions with the use of *spolia*. The adjoining water infrastructure testified to building and restoration projects between the 2nd and 7th centuries.[117] It is possible that after the early 6th c. earthquake, the paved surface was raised with a fill, which was interpreted as debris from the earthquake. The earth-beaten walking level covering the former street remained in use until the 7th c.[118] There are no indications that this new level was also re-paved.

The Removal of Pavements and Abandonment of Street Surfaces

As has already been discussed, paved surfaces were only found in a few of the excavated trenches. Whereas some streets seem to have been maintained in Late Antiquity, albeit reduced in width, others were apparently stripped of their paving, according to the underlying stony substrate which has been exposed. The evidence will now be presented in chronological order.

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[115] Waelkens *et al.* (1997) 171; Waelkens *et al.* (2000) 232, fig. 22.

[116] In the restoration drive following the earthquake, the priorities of the citizens, or official authorities, were the other buildings of the town, see also Tsafir and Foerster (1997) 108, for the priorities at Scythopolis after a devastating earthquake.

[117] See, *Unpublished Preliminary Report of the 2004 Excavations at Sagalassos* (2003) 103–105.

[118] Waelkens and Talloen (2005) 426. The damage caused by the 7th c. earthquake was apparently no longer cleared at some parts at the site. In this area, the debris formed the basis for a post-7th c. rubble-built water supply channel (interior dimensions: 13–16 × 9–15 cm) with a stepped floor of tiles, which descended from the Upper Town across the Macellum and the former west portico of the Lower Agora, see Martens (2004) 508 and (2006) 183, fig. 2.

The removal of paving slabs was noticed at the urban villa that is currently under excavation (fig. 1, fig. 2, fig. 3). At some point from the early 4th c., this domestic complex appears to have incorporated part of a formerly important longitudinal street, which had passed along its western edge.[119] Between the mid-5th and mid-6th centuries, a new, compact, and stony level, similar to the substratum usually supporting slabs, was placed over the vault of the main sewer that ran below the former street. This new level contained a number of terracotta water pipelines. Despite the initial abandonment of the street and the later re-arrangement of this stony level, its underlying sewer probably continued to function, given that several drains from the private bathing complex of the villa, as well as a toilet, directly fed this system.[120] Therefore, the former street must have become a paved alley, or a kind of courtyard, from which the service quarters of the house could be entered. Finally, at some point after the mid-5th c., or during the 6th c., the paving slabs of this 'courtyard' would appear to have also been removed.

Another example of the apparent abandonment of streets, even in the Late Imperial period, was found in the eastern residential area. Here, a major longitudinal artery leading toward the Library-Fountain complex to the north, appeared to have already been abandoned and dismantled in the (later) 4th c. (fig. 1, fig. 2, fig. 3). Although no actual paved surface was found in the TSW5 trench that was excavated, the street could be identified on the basis of stratigraphical evidence, the architectural context of an adjoining ashlar building, and a U-shaped water channel running along the façade of this building and the edge of the street.[121] Part of the ashlar building had been (re)furnished or re-organised during the 3rd c. A.D., and then abandoned in the course of the 4th century. The street must have been (partly?) abandoned at the same time, and the water channel that ran alongside it dismantled. These operations are likely to have involved the removal of its covering stones and floor. The removal of the original w. 2.50 to 3.40 m street pavement, along with a retaining structure that probably supported its eastern edge, caused part of the street's substratum, including middle imperial terracotta water pipelines, to erode down the slope.

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[119] This event used to be dated to the 6th c., see Waelkens *et al.* (1997)198, but on the basis of Dr. I. Uytterhoeven's postdoctoral research on the architecture of this urban villa, a new date could be proposed, see Uytterhoeven and Martens (forthcoming).

[120] Martens (2001) fig. 13 and (2006) 182, n. 34; Martens *et al.* (forthcoming).

[121] The channel was built of mortared rubble with a rectangular section (d. 50 cm; w. 35 cm). The interior walls did not show a full mortar coating, although this may have deteriorated through time. For the full report of this excavation by F. Martens, see *Unpublished Preliminary Report of the 2004 Excavations at Sagalassos* (2004) 91–102.

The removal of the street slabs may have occurred during the first half of the 4th c.[122] This date coincided with both the abandonment of the ashlar building, bordering the street to the East, and the destruction and abandonment of the nearby Neon Library and surrounding structures.[123] Therefore, it is possible that part of this urban quarter was abandoned at a time when the town at large was still prosperous. However, geo-radar profiles taken across the same street to the south, suggest that the paving slabs there were preserved *in situ*, which may indicate that the phenomenon was in fact rather local, and should not be extrapolated to the whole of the eastern residential area.[124]

To the north of the late antique workshop north of the Upper Agora, the substratum of the late 4th to early 5th c. latitudinal thoroughfare was exposed to a depth of over *ca.* 1.10 m. Stratigraphical evidence suggests that the slabs of this street, as well as part of its central substratum, were removed during a re-construction phase that may have coincided with the erection of the late antique fortification wall and new city gate just north-west of the workshop area, during the early 5th c. (see above). As mentioned, this former street level was raised considerably and re-paved during the second half of the 6th or early 7th centuries.[125]

A compact, stony, late antique surface was also exposed in the northern half of the North-South Colonnaded Street, where the NS1 trench was dug. It contained terracotta pipelines and evidence of a late antique encroachment upon the former street surface (fig. 1, fig. 2). It could not be decided whether a pavement was also applied to the substratum when it was laid out, between A.D. 450/75 and A.D. 550/75.[126] At the very least, these slabs must have been removed before part of the street was given up and the rubble-built structure encroaching upon the former street erected on top of it. It might be the case that the street was not entirely abandoned, but just narrowed so that only its former edges were lost. A short distance to the north, the northern offshoot of this main North-South Street (trench NS2) had clearly already been abandoned from the early 5th c. The exposal of the stony substrate indicated that the original paving slabs were removed, except for those covering a U-shaped drainage channel, which presumably continued to function.[127] The abandonment of this street may have been connected with the construction of the late antique fortification wall, which seemed to block this street to the north.[128]

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[122] The level that slid down the slope contained pottery dating to this period and was gradually covered with an erosive level containing pottery from the second half of the 4th c.

[123] Waelkens *et al.* (2000c) 426; 435–37.

[124] At Ephesus, e.g., the ruins of Hanghaus 2 seem to have been ignored for several centuries, despite the position of the building in a built up area along the main street of the city, Ladstätter (2002) 37–39.

[125] Waelkens *et al.* (1997) 168–171; figs. 101–103; see also above.

[126] For a full report of the NS1 and NS2 excavations, see Martens (2004) 450–51.

South of the Lower Agora, along the southern half of the main longitudinal axis, the paving slabs of the western portico (trench SSC1) of the Colonnaded Street were removed at some point during Late Antiquity, once again resulting in the exposal of the stony, compact substratum of paving slabs (fig. 1, fig. 2, fig. 4).[129] However, the southern half of the actual North-South Colonnaded Street was apparently still maintained during the final phase of large-scale occupation at Sagalassos.[130] Phases of re-construction and re-arrangement are attested for the shops of the western portico of this street, during the late 4th-early 5th c. at the southern end, and between the mid-5th and mid-6th c. at the northern end. There are other examples at the site of shops along the agora that were still being subjected to construction work during the later phase of occupation.[131]

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[127] This drainage channel was h. 100 to 115 cm and w. 50 to 60 cm. Pottery found within and upon this system dated to between the mid-5th and mid-6th centuries, but the strata of the former street surface could not be excavated due to the narrowness of the trench at this depth.

[128] This was deduced from the architectural remains at the surface, which allowed a re-construction of the position of the Fortification Wall at this point. A similar situation was recorded at Nicopolis, see Poulter (1995) 67–112.

[129] For a full report of the SSC1 trench, see Martens (2004) 451–51. For the SS1 excavation, see *Unpublished Preliminary Report of the 2005 Excavations at Sagalassos* (2005) 119–136; *Unpublished Preliminary Report of the 2006 Excavations at Sagalassos* (2006) 82–90; the latter by I. Jacobs.

[130] The 2005 excavations showed that the pavement of the Colonnaded Street was relatively well-maintained into Late Antiquity. There were clear signs of repairs, for instance, tile and smaller stone slabs along the western edge of the street, whereas along the eastern edge of the street, a row of slabs had been removed, probably thanks to maintenance work on the underlying terracotta water pipelines. At least two ill-constructed rubble walls were recorded, which encroached upon the street surface, but which probably post-dated the Early Byzantine period, see *Unpublished Preliminary Report of the 2005 Excavations at Sagalassos* (2005) 119–36.

Finally, the street approaching the Lower Agora from the north-east (fig. 5) also became an un-paved walkway in Late Antiquity, and consisted of a compact level of gravel and pebbles.[132] Excavations showed that the exposed level must have been the original substrate, which had once supported a pavement dating to the late 1st to 2nd c. A.D. This pavement may have remained in use until Late Antiquity, when its slabs were apparently removed. Afterwards, the pavement substrate remained in use as a walkway and occupation level into the 6th c., leading to the accumulation of a deposit. A water channel composed of U-shaped terracotta segments and a water pipeline may have been inserted into the substratum, either during the Middle Imperial period, or the Late Roman period. East of the Lower Agora, as mentioned, the raised walkway of the dismantled street between the eastern portico and the Roman Baths remained in use until the 7th c.[133]

Discussion

The general overview of the condition of Sagalassos' urban fabric in Late Antiquity clearly demonstrates that it underwent an evolution; from an initially still vital early-Byzantine city to the decaying urban centre of the later 6th to early 7th c. Although the evidence generally supports this reconstruction, the results of test-soundings nonetheless warn us that the material remains cannot be unequivocally interpreted as indicators of either the 'continuity' or 'decline' of a 'Classical city'. Rather than objective truths, the archaeological evidence for the chronology of the transformation of the urban fabric provides us with a context within which the concepts of 'continuity' or 'decay' may be debated.

Levelling operations seem to have been regularly carried out in street layout works at Sagalassos, as at other cities, and, during Imperial times, were applied to the site as part of building projects.[134] They sometimes involved the replacement of existing street levels with newly-arranged streets. The levelling operations that were carried out in response to earthquake damage, however, demonstrate the town's ability to recover, and the will and means of its authorities to enact 'maintenance work'.[135] While, in some cases, streets were covered with a new level that was not necessarily paved, in others, earthquake debris was cleared and paved surfaces restored. The pavement of the southern half of the North-South Colonnaded Street has remained well-preserved until modern times, which implies that it is an example of the latter.

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[131] Waelkens *et al.* (2006) 228, 229, 232.

[132] Waelkens *et al.* (2004) 221.

[133] Waelkens and Talloen (2005) 426.

[134] Levelling operations as part of building operations were attested in Early Imperial times in the eastern residential area (trenches TSW1 and TSW2), during the 1st or 2nd centuries A.D. for the street passing to the north of the Upper Agora, and

At the same time, the 'abandonment' of streets should not be categorically interpreted as a sign of either neglect or decay. For instance, two streets were apparently given up in the eastern residential area during the first half of the 4th c., when Sagalassos was generally still flourishing.[136] It would be tempting to link the abandonment of the street in the northern half of the quarter to the internal disruptions, which also resulted in the destruction of the nearby library. However, the results of the geophysical survey (geo-radar) show that this was instead a local development as street paving was still preserved further south. A more extensive excavation is now required to cast light on the fate of this particular urban quarter during Late Antiquity. Evidence from towns like Ephesus suggests that even extremely prominent parts of otherwise flourishing ancient cities could be (temporarily) abandoned. Indeed, even if the north-western part of the eastern residential quarter of Sagalassos did not recover its former status during Late Antiquity, evidence from other areas of the site does not point to its general economic decline during this period.[137]

Streets could be abandoned for other reasons, including changes to the internal dynamics of the road network within which they were located. For example, in the 5th c., regional political developments led to the construction of a new fortification wall at Sagalassos. This

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during the late 1st or early 2nd centuries for the street giving access to the Lower Agora from the north-east.

[135] At the Lower Town, the level of the street between the eastern portico of the Lower Agora and the Roman baths is believed to have been raised thanks to debris from the early 6th c. earthquake.

[136] In the southern half of this urban quarter, part of a longitudinal street was incorporated by a luxurious private villa, which would represent a very early example of encroachment. The abandonment of a street (trench TSW5), its water infrastructure, and part of the adjoining building was attested in the northern part of the urban quarter, *ca.* 70 m south of the Library that was destroyed after the mid-4th c.

[137] Martens (2005) 248–49.

operation seems to have caused the abandonment of an important street, which was now blocked and the re-arrangement of another.[138] The area beyond the fortification wall continued to be occupied.[139]

We should bear these factors in mind when approaching the evidence for the crucial period of A.D. 450/75 to 550/75. During this period ('phase 8' of the typological sequence of locally-produced table wares),[140] two apparently contradictory processes affected the street layout at Sagalassos. First, some streets were narrowed, but became more monumental in appearance.[141] Second, other streets were stripped of their paving slabs, leaving their stony substratum exposed. Whereas the first development suggests that there was still an active concern to maintain the urban infrastructure, the second points to neglect and possible decay. Interpreting these evolutions is difficult, having been the subject of a recent article by Luke Lavan, which suggests that political imperatives were responsible for the maintenance and improvement of the main avenues of the city, at the expense of minor roadways.[141b] The nature of any of this evidence is far from straightforward, even as it relates to the removal of the paving slabs. The exposed stony substrate of the street approaching the Lower Agora from the north-east proved to belong to an initial phase of the street layout, suggesting that the slabs that had originally covered it were in fact removed during Late Antiquity. Conversely, the exposed stony substrate of the northern half of the North-South Colonnaded Street seems to have been established during Late Antiquity. Meanwhile, an effort was made to create a new surface for the narrowed street in the eastern residential area. In these ways, the removal of paving slabs represented 'continuity' rather than 'decline'.

The overview of the ways in which the urban fabric of Sagalassos was maintained showed how substantial efforts were undertaken to repair the damage caused by the earthquake of the early 6th c., which must have affected the street network. It is likely that un-damaged building materials, including street paving slabs, were collected and used to restore the most vital arteries. As such, important streets like the Western Colonnaded Street may have been repaired first. This monumental avenue led to the church that had once been the Apollo Klarios temple, and the Lower Agora further east. Other important streets, such as the northern part of the North-South Colonnaded Street, acquired new substrata. However, for some reason, only the narrower part of this street seems to have been paved, unless the compact, pebbled surfaces of the other sections remained in use as walking levels, and never received slabs. It is possible that the same process took place in both the north-east access way to the Lower Agora and the eastern residential area. A planned programme of repair may have been interrupted, or de-prioritised in some areas of the town.[142] As it stands, the pottery evidence only allows us to generally classify this period as mid-5th to mid-6th c., and postulate that it was characterised by a devastating earthquake at some stage. Without more precise dating evidence, it will not be possible to re-construct the sequence of events that resulted in the re-organisation of the street network during this final phase of prosperity at Sagalassos.

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[138] The northern offshoot of the northern half of the North-South Colonnaded Street was apparently abandoned at this point, and its paving slabs removed, after it was blocked to the north by the late antique fortification wall. The street passing to the north of the Upper Agora was re-arranged, its original pavement being removed, around the time when the Late Roman fortification wall was built and a new city gate was erected north-west of the Upper Agora, where the street pierced the town wall.

[139] Martens (2005) 248–49.

[140] Poblome (1999).

[141] This was especially the case for the latitudinal Colonnaded Street. Further, the west-east street that was intersected at the TSW4 trench was re-built between the mid-5th and mid-6th centuries. The street approaching the Upper Agora from the north-east was re-built with a reduced width, perhaps after the 6th c. earthquake.

[141b] Lavan (forthcoming).

Finally, the smaller width of the newly-laid streets is a significant development. It could be viewed as a sign that the maintenance of the urban infrastructure of Sagalassos continued, but has also been seen as one of the symptoms of the 'decay' of the ancient city, or an indication of the transition of the classical 'polis' to the Byzantine city.[143] As mentioned above, we consider it significant that the narrower street widths at Sagalassos still conformed to the basic dimensions of 2.40 m, or 8 roman feet, which were required for wheeled traffic moving in one direction. On the other hand, however, the absence of wheel ruts at Sagalassos could suggest that wheeled traffic no longer frequented the city. Indeed, the gradual abandonment of carts and chariots in favour of pack animals, for which narrower streets sufficed, is typical of Byzantine cities.[144] French suggested, among others, that the 6th c.

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[142] For the various factors which may have provoked the onset of decline, see Vanhaverbeke *et al.* (2004), Vanhaverbeke *et al.* (forthcoming), Waelkens *et al.* (2006) 247–48.

[143] See Tsafrir and Foerster (1997) 141; see also Kennedy (1985) 11–12, 26.

[144] Bulliet (1975).

was a crucial period in the region for the transition from vehicular to non-vehicular roads, on the basis of the evidence of the *Via Sebaste* which connected the Pamphylian coast to Pisidian Antioch and crossed the territory of Sagalassos.[145] At Sagalassos, bone remains of dromedary—not camel—were identified in two Early Byzantine contexts, although other pack animals, such as donkeys, or mules, and also horses, are better represented.[146] Pack animals will undoubtedly have played an important role in urban transport at Sagalassos, simply because many slopes were too steep for wheeled transport (see above). The available evidence, however, is still too scant to contribute to this debate on the transition to non-vehicular traffic in the region.

The network of streets of Sagalassos was clearly well-maintained into the Early Byzantine period. Nonetheless, while important spaces, such as the agorae, plazas in front of monumental buildings, and some of the main streets, retained their paving, an increasingly pragmatic use of urban space during the 6th c. meant that public streets were swallowed up by what look like private structures, blocking the thoroughfare in places.[147]

In conclusion, the evidence from Sagalassos offers an insight into the evolution and maintenance of the street network of a town that gradually evolved from a classical city into a more rural site after the mid-6th c. The research methodology of using test-soundings proved useful, although the limited scale of the evidence necessitates its combination with data from other archaeological field work at the site, so that a more differentiated picture can be built up. Future research will involve further trenching and geophysical research (magnetometry and georadar) to investigate the evolution, use and maintenance of the street network during the final phases of large-scale occupation at the site.

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[145] French (1993). French proposed a date for the layout of three successors of Roman roads in Syria, Cilicia and Pisidia, which were now arranged as non-vehicular roads, often with a different alignment and without wheel ruts, in the period, A.D. 500–625. Based on literary evidence, he argued that the requirement and use of vehicular roads in the region seemed to continue until the 6th c., whereby the road-building activities under Justinian (A.D. 527–565) formed a *terminus post quem* for the introduction of non-vehicular roads, see French (1993) 449–50 with references to literature on the introduction of camels in Asia Minor during the Early Byzantine period.

[146] I kindly thank W. Van Neer and B. De Cupere, who study the archaeozoological evidence of Sagalassos, for this information. On faunal remains at Sagalassos, see also De Cupere (2001).

[147] This was certainly the case for the west-east street in the eastern residential area (TSW4). The northern half of the North-South Colonnaded Street (trench NS1) was also encroached upon in the 6th c.

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ANTIQUE ENGINEERING IN THE BYZANTINE WORLD

Michael J. T. Lewis

Abstract

This paper presents an overview of the extent to which the Byzantine Empire preserved the engineering traditions of the ancient world, passed them on to Islam and back to the West, and modified them to meet its own requirements. After about A.D. 600, expensive works of civil engineering became rare, but machines for military and agricultural purposes remained in constant and even increasing use, while fine technology saw some revival.

Introduction

In both civil and mechanical engineering—to use modern terms which had no currency at the time—classical Greece and Rome were famously and sometimes spectacularly proficient. In the course of the 5th and 6th centuries A.D., the West, with the partial exception of Italy, lost many of the more sophisticated concepts and devices. The question is how much survived in the East, especially during the upheavals which accompanied the spread of Islam in the 7th c. and left the Eastern Empire, in its so-called 'Dark Ages', with its back to the wall. The nature of most surviving Byzantine literature (which is little concerned with mundane practicalities), the relative paucity of the archaeological evidence, and the relative indifference of scholars, do not allow an easy answer. However, an attempt to move towards even the broadest and most preliminary of overviews is worthwhile.[1]

While there was, after the age of Justinian, an undoubted decline in scientific enquiry and indeed in scholarship in general, interest in mechanical theory did not wholly die out. The works of Archimedes

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[1] As yet no general survey of Byzantine engineering exists, as there is for Antiquity, China, Islam and medieval western Europe, e.g., Landels (2000); White (1984); Needham (1954); Hill (1993); White (1964).

L. Lavan, E. Zanini, and A. Sarantis (edd.) *Technology in Transition A.D. 300–650*
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and Heron of Alexandria, for example, were still read, still copied, and in the case of Heron, re-edited. Likewise, in the revival of the 9th and 10th centuries, old technical treatises on artillery and surveying were still read and revamped. We know that in the early 9th c., the library of Leon the Mathematician, the brightest intellectual star of his age, contained books on astronomy, mathematics and mechanics.[2] Around the same time, it is said, Muslims frequently asked for, and were given, copies of technical treatises, some of which survive only in Arabic translation.[3] Interest in the theory of engineering, although partly antiquarian, undoubtedly continued.

A more practical question is how far practical engineering survived. We may discern a watershed in around A.D. 600. Until then, the antique tradition which served both necessity and luxury was still very much alive; and it seems to have enjoyed its final fling under Justinian, although the unusually full literary sources for his reign may distort the picture. But after (very roughly) A.D. 600, the fabric of society and of the economy was so altered that engineering priorities were also changed, and more expensive public works were largely if not entirely given up, unless authorised by military need. This is of course a very generalised answer to the question. There was some recovery, if intermittent, from the 8th and especially the 9th centuries, and in periods of prosperity even some items of luxury were revived.

Civil Engineering

The broad pattern is exemplified by costly civil engineering undertakings, like aqueducts, bridges and harbour works, and major public buildings. After the chaos of the 3rd c., these had seen considerable revival, if not perhaps to the level of their heyday in the 2nd c. At least the major part of the greatest aqueduct supplying Constantinople itself—the line from Vize, at more than 242 km by far the longest in the ancient world—was apparently built in the 4th and 5th centuries,[4] and Procopius, whether or not he exaggerates, tells us much about Justinian's energy in this direction.[5] But thereafter, literature records little more than the occasional repair of existing aqueducts at Constantinople[6] (although the work of Andronicus I in the 1180s seems to have been more than restoration). The same no doubt applied at other major cities—one of the supply lines to Antioch, despite its capture by Muslims and Crusaders, was still operating at the end of the 12th c.[7]

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[2] Katsaros (1993).

[3] Rosenthal (1975); Gutas (1998) 176–86.

[4] Çeçen (1996); Crow and Bayliss (2005); Crow, this volume.

So too with bridges: although, after Justinian, they were still undoubtedly constructed and maintained by both the State and the Church,[7] literature records very little detail on either. Occasional exceptions include the great timber bridge over the Danube built under duress for the Avars in the 570s,[8] one in Thrace rebuilt by Constantine V in about A.D. 770,[9] and the evidently impressive arched bridge at Rhegion just west of Constantinople, rebuilt by Basil I in the 870s.[10] Late antique and Early Byzantine bridges show little technical advance over their Roman prototypes except that one may detect a move towards hollow spandrels for lightness,[11] towards flat segmental arches for low bridges,[12] and, following Syrian architectural models, towards slightly pointed arches for high ones.[13]

By the same token, few if any new harbours were built after the 6th c., nor reservoirs, nor large public baths. Large-scale vaulting declined, as did large-scale terracing and urban fortification, despite the fact that civil engineering technologies survived amply in the Early Islamic Levant and even to some extent in Italy.[14] While maintenance of existing structures sometimes, or perhaps usually, continued, new construction—a very different matter—markedly decreased. Overall, it seems clear that civil engineering suffered a severe setback.

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[5] Of Justinian's bridges, the best documented is the Sangarios: Whitby (1985), for better photographs, see Mango (1976) 126.

[6] Summarised by Dirimtekin (1959) 242.

[7] Wilber (1938) 52.

[7] See, for example, Millet (1949).

[8] John of Ephesus, *Hist Eccl.* 6.24; Zonaras 14.11.

[9] Mango and Ševčenko (1972).

[10] Constantine Porphyrogenitus, *De administrando imperio* 51.

[11] E.g., Makestos: see Wiegand (1904) 300–1 and Taf. XXIV.

[12] E.g., Limyra: see Wurster and Ganzert (1978).

[13] E.g., Karamağara: see Mango (1976) 129 and pl. 138.

[14] See Crow, this volume; Arce, this volume; Coates-Stephens (1998).

Machines

Machines offer a fuller and more interesting picture. The basic tools inherited from the past—the drill, the lathe, the bellows and so forth—underwent no significant change. But, symptomatic of the needs of the age, military technology saw considerable innovation.

Military Machines

Ordinary artillery—the ballista and onager—had for centuries been based on the torsion principle, where the energy was stored in twisted springs of cord.[15] Effective though it was, however, its technology was complex and its springs temperamental. From the late 6th c., the onager for throwing stones was rapidly replaced by the very much simpler but equally effective *petraria*, or traction trebuchet, powered by men pulling on ropes. This is first attested in the West probably in A.D. 586, the design having arguably been borrowed from the Turks with whom Byzantium had been in diplomatic contact for the decade following A.D. 568, and who had themselves picked it up from the Chinese.[16] In turn, in the 12th c., there are strong signs that the traction trebuchet was developed by the Byzantines into the even more powerful counterweight trebuchet powered by a falling weight, which likewise became the standard siege engine across Europe and Asia.[17] Similarly, around A.D. 600, the arrow-shooting ballista, powered by torsion, was superseded by the simpler *toxoballistra*, or crossbow. This whole area was one where antique technology proved unsuitable. Complex manufacture and skilled operators gave way to the less sophisticated construction and largely unskilled labour, which were more appropriate for the new circumstances.

The reverse process, however, took place with the most renowned and most feared of Byzantine weapons, the Greek fire projector. In effect a napalm thrower for naval warfare, it began life in the 670s apparently as a simple hand-held squirt—not unlike a bicycle pump—squirting crude oil that had been perilously heated over a fire to reduce its viscosity and increase its flammability. But somewhere between *ca.* A.D.

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[15] Marsden (1969) and (1971), which are weak on the artillery of Late Antiquity. For a brief survey of this, see Lewis (2004).

[16] Chevedden, Shiller, Gilbert and Kagay (2000).

[17] Chevedden (1998) and (2000).

750 and 850, it evolved into a much more complicated machine which combined the two-cylindered force pump of the ancient world with the swivelling nozzle of the fire-fighting engine, and its fuel was now an unheated light crude, or even, arguably, distilled petroleum.[18]

Agricultural Machines

On a humbler plane, workaday machines for food production and processing continued in unbroken sequence, and even proliferated in number, although not in sophistication. Antiquity had built up a whole range of water-lifting devices for irrigation, domestic supply and mine drainage, all of which survived. These included not only the simple, age-old *shaduf*, or rocking beam, but also the more complex Hellenistic inventions—the bucket-wheel, or chain of pots powered by man or animal or water, the right-angled gears which are sometimes necessary to turn them, and the Archimedean screw.[19] All were widespread in Egypt and Syria long before the Arab conquests, and all flourished there ever after. In territory which remained Byzantine there was less need for irrigation, but there is evidence that similar machines were not forgotten in Crete and Asia Minor.[20]

Another of these Hellenistic machines was the force pump or siphon, which demanded greater precision in the making. References in literature show that it remained in use until at least the 10th c., and at least for fire-fighting in Constantinople. St. Stephen the Younger, for example, was martyred in A.D. 764 by iconoclasts who hit him on the head with the handle of such a pump.[21] In the West, the force pump certainly expired in the 5th or 6th c. and is not heard of again until the Renaissance. Quite possibly it was then borrowed back from Byzantium.

Another machine which continued in unbroken succession was the oil press, whether operated by weighted lever or by screw.[22] Yet another was the mill. Hand and animal mills continued.[23] So too, above all, did the watermill, another Hellenistic invention. It used to be thought that in Roman times it was still a rarity, but archaeology is now revealing that it was already relatively widespread,[24] and that it was used not only for grinding flour, but also for pounding grain, fulling, sawing, metal ore-crushing, and iron-working.[25] In post-Roman times, both the vertical- and the horizontal-wheeled variety proliferated even more, in both west and east, in any terrain suitable for water power. From Byzantine monastic *typika* and *praktika* we know that the watermill was widespread at least in Thrace, Lemnos, Crete, Asia Minor and Sicily. It could be large, with multiple wheels at the same level (called, for example, a 'three-eyed mill'), or even—like the earlier instances at Barbegal in France and the Janiculum in Rome—stepped down a hillside. Such a ten-step mill for sawing, built in the 7th c., has been identified at Ephesus.[26] The watermill was also transmitted northwards to Russia and eastwards to India, Sassanian Persia, Oman, Armenia, and Iraq (where a massive installation is said to have been built in Baghdad, in around A.D. 775, by a Byzantine).[27] Whether the early watermills of China were indigenous, or were borrowed from Rome and Byzantium, remains an open question.

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[18] Haldon (2006).

[19] Oleson (1984); Schiøler (1973).

[20] *Acta et diplomata graeci medii aevi* 6.96; Ibn Battuta 433, 436.

[21] *Vita Stephani Minoris* 169.28–30.

[22] Mattingly (1988).

[23] E.g., an 11th c. miniature of Samson operating a geared mill, Cod. Vat. gr. 747 fol. 251r.

A further type of grain mill to which the Byzantines arguably made a contribution is the windmill. There are suggestions that in Asia Minor, in the 11th and 12th centuries, the vertical windmill (proposed, perhaps only theoretically, by Heron of Alexandria) was married to the horizontal windmill of Persia (brought hither by the Seljuks) to produce the post and tower mills which became so typical of the western European and Mediterranean landscape.[28]

Mining

Extraction and processing of metal ores had in Roman times been a major and highly mechanised industry, with waterpower extensively applied to hushing, stamping and probably grinding. Having in the 1st and 2nd centuries A.D. reached a scale unparalleled before the industrial revolution, it then suddenly collapsed—probably because it was so capital-intensive—and it never recovered its former level.[29] Mining and metal working of course continued, but on a smaller scale, and in Byzantine times it was clearly not insignificant[30]—although the literary and archaeological evidence is exceedingly slender—and must have employed some machinery, no doubt of Roman inspiration. But we hear of nothing except a *trochos ergastikos* at Siderokausia in Chalcidice in A.D. 1445, which was either a windlass for lifting ore up a shaft, or possibly a waterwheel for crushing.[31]

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[24] Wikander (1984) and (1985).

[25] Lewis (1997) 89–115; Wilson (2002). See also Seigne (2002) on a 6th c. water-powered sawmill at Jerash used for sawing *spolia* from classical buildings into veneers.

[26] Vetters (1981) 151, Taf. XXXI; (1982) 72, Abb. 5–11 and (1984) 225: preliminary reports only.

[27] India, Persia and Oman, Wikander (1985), 162–3; Armenia, Movsēs Dasxurançi 214; Russia, Vernadsky (1948); Baghdad, Bury (1912) 241–2.

[28] Lewis (1993).

Fine Technology: from Instruments to Toys

The survival of machines is hardly surprising if they were useful for war or, when cheap and within the ability of local craftsmen, for everyday life. What is rather more surprising is the survival, after the Byzantine Dark Ages, of fine technology in the form of clocks and astronomical instruments and even toys, which had been forgotten in the West. They seem to have flourished only at certain periods of prosperity and revival, but survive they did.

One instance was the water clock, in its basic form very simple. Around A.D. 850, Leo the Philosopher was responsible for a long-distance signalling system between the Cilician frontier and Constantinople, which depended on synchronised clocks, no doubt uncomplicated.[32] But there had also been a tradition in the eastern Roman provinces of complex clocks with elaborate jackwork and even gears, dropping balls on the hour, ringing bells and moving little figures. They continued in the big cities until at least the 13th c. At an early date, the idea was passed on to Islam, which developed it with enthusiasm.[34] It returned to the West in A.D. 807, when Harun al-Rashid gave such a clock to Charlemagne.[33] There are signs that even China had heard of Byzantine clocks.[34]

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[29] Wilson (2002). Archaeological evidence is overwhelmingly confirmed by pollutant levels in cores taken from the Greenland ice-cap.

[30] Vryonis (1962).

[31] *Actes de Xéropotamou* 30, will of the nun Nymphodora.

[32] Aschoff (1980); Pattenden (1983).

[34] Price (1959); Lewis (2000). In 10th c. Baghdad and Constantinople, Vasiliev (1950) 77, 171, 388, 392.

[33] *Annales Regni Francorum* s.a. 807.

[34] Hirth (1885) 53, 57, 213–14. Nestorian missions were sent from Syria to China from around A.D. 635: Needham (1954) 128.

Similarly the organ, yet another Hellenistic invention, was used in Byzantium, not for church music, but for imperial occasions and in the hippodrome. It was no longer worked by air pump and water reservoir, but by leather bellows, and it could be large. In this case, Islam hardly took any interest, but the organ returned to the West in A.D. 757, when Constantine V gave one to Pepin at the Merovingian court, while Louis the Pious was given another in A.D. 826.[35]

Basic land measurement continued, but in the absence of new aqueducts the more sophisticated Roman surveying instruments were probably forgotten, and an anonymous 10th c. treatise on surveying is merely a re-hash of ancient material.[36] Some precision instruments, however, did survive long enough to be transmitted to Islam. The tradition of mathematical gearing, exemplified by the extraordinary Antikythera mechanism of the 1st c. B.C., is still to be seen in the so-called London sundial-calendar of probably *ca.* A.D. 500, and al-Biruni's 'Box of the Moon' of about A.D. 1000 is a close relative.[37] The plane astrolabe, invented perhaps in the 2nd c. A.D., survived at least in Egypt until after the Arab conquest, and by the early 9th c., the Arabs were writing treatises on it. Possibly it was then forgotten by the Byzantines until the 11th c., after which astrological treatises—and an actual astrolabe—show some Arabic influence. It was certainly Islam which introduced it to western Europe via Spain in the 10th c.[38]

Finally, there were automata. The most famous and best documented were those installed by the Emperor Theophilus in around A.D. 830 in the Magnaura Palace in Constantinople, where behind the imperial throne was a golden tree with jewelled birds on the branches, and golden lions and griffins around it. The animals stood up and roared, the birds sang. We do not know exactly how they worked, but they were fully in the tradition of Heron of Alexandria.[39] Coincidentally or otherwise, they were contemporary with similar marvels in the court of al-Ma'mun in Baghdad. Around the same time, the first great Muslim mechanics, the Banu Musa, were producing their treatise on automata, which owes a large debt to Heron, and to Philon of Byzantium.[40] The mechanical ingenuity inherited from the antique world was by no means dead.

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[35] *Annales Regni Francorum* s.a. 757, 826. For a good overview of the Byzantine organ, Perrot (1971) 169–83.

[36] Lewis (2001) 56–58, 289–98.

[37] Price (1959); Field, Hill and Wright (1985); Field (1990).

[38] Lewis (2001) 67–71.

[39] Brett (1954).

Some, maybe most, of this surviving repertoire of fine technology, Greek fire projectors included, was lost in the disaster of the Fourth Crusade. But, as we have seen, much of it had already been transmitted to Islam and, between the 8th c. and the Renaissance, some of it was also transmitted back to the West, either directly, or via Islam. This transmission contributed greatly to the intellectual, scientific and industrial revolutions of later centuries.

Conclusion

Why did some technologies survive the watershed around A.D. 600 and others not? It may be, to some extent that Greek and Roman innovation had run its course, that the essential infrastructure of works such as bridges and aqueducts was already in place, and that most of the mechanical devices useful to that level of culture had already been developed. In some areas, tentative answers must be sought in the social and especially the economic sphere. Building activity in Constantinople seems to have ground to a halt around A.D. 600 because of a lack of finance and, arguably, massive depopulation. Thus, the large public baths went into gross decline, and it is symptomatic that the city's main aqueduct, cut by the Avars during the siege of A.D. 626, was apparently not restored until A.D. 767.[41] Similar factors may apply to other cities. Mechanical engineering, however, was a different matter. Wars had to be fought, and as always, they boosted technology. Agricultural machines, such as the watermill and oil press flourished because they were simple, labour-saving and within the budgets of individual proprietors. Fine technology survived only when and where municipalities or emperors were sufficiently wealthy and status-conscious. Byzantium's role then as a technical innovator was far from unimportant or unimpressive. But its role of most lasting significance was a very different one: just as it served as the custodian of ancient literature, so too it served as the custodian of ancient engineering.

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[40] Hill (1979).

[41] Theophanes *Chronicle* 440.

It has been said that the uniqueness of Byzantine culture was founded on the fusion of Roman stability, Greek intellectual vigour, and eastern mysticism.[42] For our purposes, the essential components were the scientific reason of the Greeks and the broad practical vision of the Romans. This practicality of the Byzantines was appreciated, if not by their often supercilious western neighbours, at least by their eastern contemporaries. The great Muslim scholar al-Jahiz, who died in A.D. 869, considered that 'wisdom has descended upon these three: the brain of the Byzantine, the hands of the Chinese, and the tongue of the Arab'.[43] In similar vein, a widespread saying of Chinese origin, first recorded in the 11th c., runs:

> The people of China are the most skilful of men in handicrafts. No other nation approaches them in this. The people of Rum [Constantinople] are highly proficient too, but they do not match the standards of the Chinese. The latter say that all men are blind in craftsmanship, except the men of Rum who, being one-eyed, know but half the business.[44]

...which, from China, was quite high praise.

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[42] Byron (1929) 75–76.

[43] Needham (1965) 602.

[44] Needham (1965) 602.

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BUILDING

TECHNOLOGY AND IDEAS: ARCHITECTS AND MASTER-BUILDERS IN THE EARLY BYZANTINE WORLD

Enrico Zanini

Abstract

Eastern literary and epigraphic sources from the 5th and 6th centuries A.D. mention several architects/engineers in the service of the imperial court at Constantinople. They give us an idea of the scientific knowledge, technical expertise and social status of these men. A larger group of architects and master-builders are also attested. They operated mainly in a lower-key, local context, but they also moved abroad to answer the requests of patrons. A comparison between the written sources and archaeology allows us to reconstruct some examples of the mobility of people and ideas, and to advance some hypotheses about the development of building material culture in the late antique eastern Mediterranean world.

Sovereigns and Architects

The image of the sovereign in the literary and epigraphic sources of Late Antiquity and Early Byzantium is often associated with the well-established classical idea[1] of the 'Great Builder'. The ruler was personally involved in devising, planning and directing restoration, building and re-building projects all over the empire, thus improving both the 'beauty'[2] and functionality of its cities.[3]

When, in A.D. 550–560, Procopius of Caesarea compiled *De Aedificiis*, the panegyric of Justinian, even the title testified to the tremendous significance of imperial building activity in defining the public

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[1] Pernot (1993), 418; more generally on classical background of late antique panegyric, Whitby (1998).

[2] Saradi (1995).

[3] Whitby (2000) 56.

L. Lavan, E. Zanini, and A. Sarantis (edd.) *Technology in Transition A.D. 300–650*
(Late Antique Archaeology 4 – 2006) (Leiden 2007), pp. 381–405

image of the Byzantine *autocrator*,[4] the 'Architect of the Empire'.[5] The image of the emperor directly involved in marshalling building work is among the most recurrent *topoi* in late antique panegyrics.[6] However, what literary and epigraphic texts rarely note is that great construction projects financed by imperial benefaction were always accomplished by individuals: workers, master-builders and architects with the ability to physically implement ideas, who applied their theoretical and technological knowledge to the complex task of converting raw building materials into public monuments.

When not hindered by fluctuating socio-economic conditions, the completion of a large building enterprise was underpinned by the combination of technical and technological knowledge. This expertise was normally handed down from one generation to the next, although there were times when the transmission was at risk. If it was for some reason interrupted, restoring the transmission of this expertise from one generation to the next became extremely complicated.

Such an interruption seems to have occurred in the first half of the 4th c., when the literary sources register a particular concern at the problem of handing down expertise in this field. This is demonstrated by at least three decrees of the Constantinian period mentioning a shortage of artisans specialised in construction and building decoration and, particularly, a shortage of architects.[7] A first decree was addressed to Felix, the provincial governor of Africa, and the second and the third to Maximus and Leontius, who were both likely to have been *praefectus praetorii*, in the region of the Danube[8] and in the East, respectively.[9] This means that various provinces experienced a lack of artisans and technicians. Since the Empire at this time was engaged in the extraordinary endeavour of creating the New Rome on the Bosporus, such a situation must have been more than distressing. Hence, the decision of the emperor to grant such artisans and their families quite remarkable benefits—an exemption from taxes and immunity from the complex net of civic *munera*—appears perfectly understandable.

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[4] Downey (1950); Webb (2000).

[5] This image finds a very interesting parallel in that of God as 'world architect' used in Early Byzantine patristic literature, i.e. in the *Homilies* by Germanus I, Patriarch of Constantinople, in the first half of the 8th c. (*PG*, 98.316D–317A).

[6] Constantine the Great, for instance, wrote a letter to the bishop of Jerusalem to instruct him on the organisation of the building site of the Holy Sepulchre (Eusebius Caesariensis, *Vita Constantini*, 3.30–32, *PG* 20.1091–93). Justinian seems to have imposed his heterodox solutions to complex technical and structural problems on the architects of Hagia-Sophia (Procop. *Aed.* 1.1.66–71; 2.3,8–11).

[7] *Cod. Theod.*, 13.4.1 of 334; 13.4.2 of 337; 13.4.3 of 344.

[8] *PLRE* I, 590–91 (*Maximus 49*).

[9] *PLRE* I, 502–93 (*Leontius 20*).

These imperial efforts were probably successful in preserving the uninterrupted transmission of technical knowledge. Nonetheless, at the same time, these laws reveal a new and complicated panorama of architectural planning and monumental building in Late Antiquity. On one hand, monuments continued to be erected both in the East and in the West;[10] great building yards were still using traditional materials and techniques,[11] and architectural and engineering expertise was perpetuated in one way or another.[12] On the other hand, within this framework of apparent continuity, some symptoms of decline were evident in some regions: at Rome we hear that public building was sometimes slowed down by technical imperfections;[13] whilst on some construction sites in this district, poorer building techniques and a less specialised division of labour, prefiguring medieval practice,[14] can be noted. It can also be noted that Latin late antique architectural treatises were no more than repetitions of the precepts laid down by Vitruvius.[15]

These three aspects seem to prefigure the sensitive difference between the East and the West that was to become evident in the subsequent centuries. In the West, a world was emerging in which it became ever more difficult to efficiently maintain monumental urban city centres. This is suggested by the frequent re-issuing of imperial decrees that were intended to safeguard at least the most important public buildings from dilapidation and systematic spoliation.[16] In these circumstances, there was much less opportunity for additional planning and building activity, necessary to ensure the continuity of ideas and forms, and the survival of building technologies and techniques derived from the great Greco-Roman architectural tradition.

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[10] Ward Perkins (1996).

[11] Santangeli Valenzani (in this volume).

[12] MacDonald (1977) 52.

[13] Symmacus (*Rel.* 25–26) recounts the paradigmatic history of the rebuilding of the *Pons Probi*, the future *Pons Theodosii* in Rome: the building works were very slow, the costs were exaggerated, architects and contractors were hard-working, but un-qualified, and the bridge finally collapsed.

[14] Santangeli Valenzani (2002).

[15] Plommer (1973).

[16] Baldini Lippolis (forthcoming).

In the East, in the area where the Early Byzantine Empire was taking shape, more elaborate building activity did take place in the 5th and 6th centuries, and various agents were at work: the Church was marking its eminence in the Empire by constructing places of cult worship; the State, at least during Justinian's reign, continued to strengthen the system of defence and the road network in various provinces; the municipalities were taking advantage of a last phase of economic prosperity to maintain, repair and construct public buildings and amenities; and last, but not least, a whole range of citizens—from the members of the rich commercial 'middle class',[17] to the ancient aristocracy of blood and the new aristocracy of office (ecclesiastical, military and bureaucratic leaders)—made their mark on the urban landscape by building the last generation of *domus*. However, the existence of patronage networks was just one of the conditions that lay behind the endurance of high-level building activity in the East. In reality, the more fundamental pre-condition was the continued prevalence of the material culture connected with large-scale and high-quality building activity. It will, therefore, be necessary to asses the availability of:

- raw construction materials and the capacity to select and shape them according to the desired end-product.
- theoretical knowledge—both scientific and aesthetic—necessary to envisage, plan and organise a dimensional space.
- project management, in order to develop an abstract idea into a concrete form.
- the technical ability to use technology and organise labour to transform the project into a building.

It goes without saying that every stage was equally indispensable in the transmission of material culture and technology. Yet the figure of the planner—both architect and engineer in modern terms—was particularly crucial, since he was charged with the fundamental task of translating the buyer's wish into a concrete project. He needed to possess both theoretical and operational abilities in order to manage all phases of the building process, from the formal planning stage to its functional completion.

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[17] On the evolution of the socio-economic role of the middle-class in early Byzantine cities, see Zanini (2006).

It is in such terms that the figure of the architect is mentioned in late antique sources.[18] The most explicit textual evidence comes from the Ostrogothic court of Ravenna. In a famous passage of the *Variae*, in which Cassiodorus reported the *formula* for the appointment of a *curator palatii*, explicit reference is made to the role of the court architect:[19]

> When we are thinking of rebuilding a city or founding new forts, we would be delighted if you could build for us the pleasantness of a *praetorium*, and we shall rely upon you to bring our ideas to everybody's eyes. The mason, the marble-cutter, the brass-maker, the builder of vaults, the plasterer, and the mosaicist all will ask you about anything they are unsure of, and so, an army of artisans will come to you for orders, so as to avoid any kind of mistake.[20]

Cassiodorus' words probably recalled a prototype *formula* from the Constantinopolitan chancellery, or at least referred to a lost Late Roman antecedent. They allocated two basic assignments to the court architect:[21] one of a conceptual nature; and one organisational. The first, alluded to in the first sentence, was related to the ability to make the ideas of the sovereign 'visible'; in addition, the architect was requested to become the conductor of the building process, the first referee for each of the specialist craftsmen involved, who would profit from his more sophisticated theoretical and technical knowledge.[22]

No comparable document is preserved in the sources more directly connected with the 5th to 6th century Constantinopolitan court, but the presence of a similar figure in the Great Imperial Palace can be assumed on the basis of some convergent considerations. The existence of some 'centralised planning service' for public works and single monuments was apparent in many cases, first of all in newly-founded cities. A particularly well-known example is that of Dara in Mesopotamia, the walled city founded by Anastasius in A.D. 505–507, around the same time that Cassiodorus compiled the *formula* at Theoderic's court. The foundation process of the 6th c. city is described in considerable detail in *The Chronicle of Zacharias Scholasticus*,[23] thus allowing us to follow every single phase. The commanders of the imperial army had decided to build a new fortress on the Persian front, and selected a location on the basis of their strategic requirements. The emperor entrusted the Bishop of Amida, the region in which the stronghold was to be located, with the management of every step of the construction. The bishop sent out an experienced topographer to draw a map of the area and to pick out some possible locations. This map was then dispatched to the capital and formed the basis on which the emperor and his staff decided exactly where Dara would be built. The bishop of Amida, who was asked to manage the hiring of necessary personnel, recruited many locals, but also engaged artisans from Constantinople.

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[18] Vagnetti (1979) 116–22.

[19] Cassiod., *Var.* 7.5 (*CSC*, XCVI, 264–65)

[20] Nam sicubi aut civitatem reficimus aut castellorum volumus fundare novitatem vel si construendi nobis praetorii amoenitas blandiatur, te ordinante ad oculos perducitur quod nobis cogitantibus invenitur [...] Quicquid aut instructor parietum aut sculptor marmorum aut aeris fusor aut camerum rotator aut gypsoplastes aut musivarius ignorat, te prudenter interrogat et tam magnum ille fabrilis exercitus ad tuum recurrit iudicium, ne possit aliquid habere confusum...

[21] It is unclear if the Aloisius *architectus* referred to in another place in the *Var.* 2.39 (CSC, XCVI, 84–86) could be connected with this juridical figure.

[22] This double-edged knowledge originated in the clearer distinction between the architect-planner and the architect-builder which can be observed in Greco-Roman tradition: cfr. Gros (1983); Martin (1983).

Despite its conciseness, Zacharias' text provides us with precious evidence for the complex sequence of ideas and actions leading to the formation of the city of Dara, the remains of which are still evident. This fundamental text allows us to highlight some elements of the building procedure adopted. First of all, the dense exchange of technical information between centre and periphery, mainly by means of technical drawings concerning the topographical relief, the general urban plan and single buildings was clearly vital.[24] Second, the procedure was structured hierarchically, the main elements of the urban planning being centrally directed, by the emperor himself, assisted by a group of highly specialised technicians, while locals were responsible for the executive aspects.

Third, the composition of such a large construction yard was 'mixed' in terms of material culture and technology. The work force essentially consisted of farmers who, attracted by the usual abrogation of fiscal impositions, were recruited on the spot and evidently used traditional regional building techniques. But we can also imagine technicians and specialised artisans coming from further afield,[25] in some cases from the capital, working side-by-side with these local labourers. We obviously do not know who these people were, or what particular tasks were assigned to them. However, it would be surprising had there not been professionals specialising in planning or executing complex architectural projects such as impressive town walls, which required the adoption of a variety of specific technical solutions.[26] For the planning and realisation of buildings within the urban perimeter, other skilled artisans had to be employed. This seems to be confirmed by the implementation of standard urban installations, including at least one great church, a large public bath, a warehouse, an aqueduct, some cisterns and a network of colonnaded streets.

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[23] *Hist. Eccl.*, 7.6; ed. Hamilton, Brooks (1899) 164–68.

[24] On the circulation of drawings of plans, as a means of communicating spatial ideas in a non-linguistic form in the Greek world, cfr. Coulton (1983); and in the Roman world, cfr. Taylor (2003) 27–36.

[25] The *Chronicle* by Joshua the Stylite (ed. Wright (1882) 70) reports the recruitment of "selected workmen from all Syria".

'Centralised' planning, as apparent in the case of Dara, is likely to have been the rule rather than the exception. This was confirmed a few decades later in an account by Procopius on Dara. The recurrent flooding of the river crossing the city[27] called for ingenious fortifications and hydraulic engineering. In this case, the procedure was again clear-cut: a particularly violent flood caused the partial collapse of the city wall; Crises of Alexandria, the *mechanopoios*, asked for intervention from the capital; in Constantinople, Justinian summoned Isidorus of Miletus and Anthemius of Tralles, the two *mechanikoi* of the court, who each designed a proposal; the emperor, in turn, was inspired by a vision and suggested a third solution; he then commanded his architects to translate his idea into a concrete project that could be returned to Crises, who was entrusted with the construction of a complex system of dams and current-regulators.[28]

Procopius' account explicitly underlines the central role of the two court-architects, Anthemius and Isidorus. Like the architect referred to by Cassiodorus, they were the guardians of a sophisticated, theoretical and practical culture of architecture and engineering. Both of them wrote important theoretical treatises in the fields of geometry and statics: Anthemius was the author of a famous, partially-preserved[29] essay on geometry,[30] and was a gifted commentator on mathematical texts;[31] Isidorus produced a now lost commentary on Eron of Alexandria's essay on vaults. This solid theoretical base allowed these men to treat the planning of a new city, and the construction of a dam in Mesopotamia or the church of Saint Sophia in Constantinople, in exactly the same manner. For the Great Church, they designed an ingenious system to divide the enormous weight of the dome over the half-domes and pillars beneath it.[32] Therefore, this building represents an ideal case-study to demonstrate the ability of these architects to apply mathematical principles and geometric, structural calculations to architectural planning.[33] Some of their solutions, for example, the adoption of imprecise and/or incalculable curves at critical points of the vaulting system, testify to the creativity of Anthemius and Isidorus, and show that they were able to reconcile 'canonical' planning with improvised solutions.[34] The last element is of great importance in comprehending how their intellectual versatility enabled them to fuse theoretical knowledge with an acquaintance of traditional Roman building techniques[35] and related technology. This understanding is demonstrated by a combination of literary sources and the few archaeometric analyses currently available.

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[26] Zanini (1990).
[27] Procop. *Aed.* 2.3.
[28] On the hydraulic system associated with Dara's city walls, cfr. Furlan (1984).
[29] Huxley (1959).
[30] Lassus (1958).
[31] Cameron (1990).

Procopius' *De Aedificiis* is again a vital source.[36] Despite its panegyric nature, the importance of this book deserves to be re-evaluated, since the author was clearly capable of describing architectural projects, correctly using somewhat complex technical language.[37] In at least two passages of his long piece devoted to the construction of the Great Church, Procopius refers to the sophisticated knowledge of Anthemius and Isidorus concerning the properties of materials.[38] This is apparent in his accounts on the use of lead joints and the quality of the mortar employed. The mortar apparently dried very quickly—the construction of the church took only six years—in spite of the typically thick, horizontal joints of this period.[39] Lead was used in the joints of the pillar blocks, either in thin, interposed sheets,[40] or by straining fused metal,[41] in order to divide the load equally over the entire stone surface. It probably also served as elastic and earthquake-proof binding, common in both the Greek and oriental worlds.[42] The first available technical and structural analyses of the brick masonry partially confirmed the quality of the building technology responsible for it. In particular, the recent re-examination of a sample taken during the restoration projects of the 1940s has shown that the mortar in the base of the dome possesses a stronger cohesion and gliding-resistance than that habitually used in western medieval architecture.[43]

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[32] Taylor (1996).

[33] Warren (1976).

[34] Emerson, Van Nice (1951a), Mainstone (1988) 159–217.

[35] MacDonald (1958).

[36] Mango (1992).

[37] Howard-Johnston (2000) argues that Procopius himself had a specific architectonic expertise. However, other panegyrists, including Coricius of Gaza and Constantine Rhodius appear to use architectonical and/or engineering terminology properly and, in some cases, explicitly (Coricius *Laud. Marc.*, 1.27); (Downey 1946).

[38] Procop. *Aed.*, 1.1.21–78.

[39] It is possible that the static problems reported by Procopius (*Aed.*, 1.1.71–77), which were clearly related to the collapse of the first dome of Hagia Sophia (Conant 1946) were caused by the mortar drying too quickly.

The two imperial *mechanikoi* were also charged with co-ordinating the hustle and bustle of an elaborate, multifaceted building site. The *Narratio de Sancta Sophia* provides us with the astounding fact that 10,000 labourers and artisans were simultaneously engaged in the project. This suggests a 'military' organisation—the workers being divided into a hundred *centuriae*, each under the command of a master builder[44]—and gives us some idea of the scale and complexity of the site.[45]

Mechanikoi at Constantinople and in the Provinces

The Church of Hagia Sophia in Constantinople is of course a unique monument. Nonetheless, monumental building activity between the second half of the 5th and the end of the 6th centuries, in the capital as well as in the provinces, suggests the existence of regional architectural schools and provincial technicians, as competent as the great court architects. In contrast to the Roman texts, in which overt references to architects are scarce,[46] Early Byzantine sources report a relatively long list of 'intermediate' architects who, although not Constantinopolitan geniuses, were not simple master-builders either. It appears that these men were authorised to execute centrally-devised plans, although they could also work independently on important and geographically dispersed projects. We know of at least six architects involved in monumental public building works connected with the central administration.[47]

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[40] Paul the Silentiaire, *Descriptio Sanctae Sophiae*, vv. 476–80.

[41] Procop. *Aed.*, 1.1.53.

[42] Arce (1996).

[43] Mark, Cakmak (1994).

[44] Preger (1907).

[45] On the organisation of the building yard of Hagia Sophia, see also Paribeni (2004).

[46] Calabi Limentani (1958); MacDonald (1982) 122–42; Anderson (1999) 3–67; Taylor (2003).

The Alexandrian *mechanikos*, Crises, is known only from Procopius' account on Dara, according to which he was in charge of most Syro-Mesopotamian buildings and fortifications. Procopius is also our primary source for the activities of Isidorus of Miletus the Younger, whose uncle designed Hagia Sophia. Together with his colleague, John of Byzantium, he worked on the reconstruction of the walls and a large bath complex at Zenobia-Halebiyye, on the Euphrates.[48] Isidorus is also commemorated by an inscription—this time mentioning him alone and possibly dating to around A.D. 550[49]—celebrating his design of the fortifications of Chalcis, in western Syria. A few years later, perhaps in A.D. 558/9, he re-appeared in Constantinople, where he was in charge of a team of architects, responsible for investigating the collapse of the old dome of Hagia Sophia, and constructing its successor with a higher profile, still visible today.[50] A fourth important figure was Theodore, 'experienced in the art of mechanics', who Procopius mentions as one of the people in charge of the defence of Dara during the Sassanian assault of A.D. 540.[51] One can reasonably assume that Theodore was the same architect who, according to the *Life of Saint Sabas* written by Cyril of Scythopolis,[52] was sent by Justinian to Jerusalem in order to supervise the erection of the new church of the Holy Virgin, the *Néa*. Procopius also mentions a constructor with the same name, Theodore *silentiarius*, at the Episcopia fortress, but this seems to be mere coincidence.[53] The activities of the imperial *mechanikos*, Victorinus, are well documented in monumental epigraphy, although he does not appear in literary sources. He was in charge of the partial re-building of the fortifications at the Corinthian Isthmus.[54] Moreover, in a series of inscriptions from Epirus, he praised himself as the designer of all the fortresses of Moesia, Scythia, Thrace and Illyricum.[55]

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[47] Feissel (2000) 87–88.

[48] Procop. *Aed.* 2.8.25.

[49] Fourdrin, Feissel (1994).

[50] Emerson, Van Nice (1951b).

[51] Procop. *Pers.* 2.13.26.

[52] Cyr. Scyth. *V. Sabae* 72–73 ed. Festugière (1962) 103–108; *PLRE*, III, 1249 (Theodorus 13); Feissel (2000) 99.

[53] Procop. *Aed.* 4.8.24.

[54] Gregory (1993), 10–12, argues that Victorinus was not an architect, but a member of the military hierarchy, possibly the *praefectus praetorio*, in charge of re-building the Isthmian fortification at Corinth.

This list can be supplemented by other figures recorded in literary and epigraphic sources, even if their identification must sometimes remain more or less uncertain. Procopius[56] mentions that a certain Thomas, probably a military commander, 'built' numerous fortresses in Lazica.[57] Stephen of Aila, whose name is inscribed on a roof beam of the monastery church of St. Catherine of Sinai, could have been the architect in charge of the whole complex,[58] or merely the carpenter who fitted the roof.[59] Asaph and Addai, who are mentioned in a 6th c. Syriac hymn devoted to the re-construction of Hagia Sophia at Edessa,[60] must have also been architects directly linked to Justinian. Sadly, further research has been made impossible by the disappearance of this church and the total lack of any additional references to it in the literary sources.[61]

Although these imperial *mechanikoi* cannot always be reliably identified, it seems that their activity was centred on the Syro-Palestinian area and in the Balkans. Indeed, we do not possess one piece of evidence explicitly mentioning men involved in similar activities in the main areas of Justinian's 're-conquest'—Africa, Italy and Spain. Since these regions had just been restored to the Empire, one would expect a gradual increase in construction activity. In the case of Italy[62] and Spain,[63] its absence can partly be explained by a genuine shortage of resources, and partly by the fact that Justinian's so-called golden age was already declining when these regions were brought back under Constantinopolitan control, thus making imperial patronage of building projects less likely. Both literary and epigraphic sources testify to imperial benefaction in Africa, however, where dozens of fortresses, rebuilt within a few years of one another, unmistakably imply central intervention. Nevertheless, neither Procopius' *De Aedificiis*, nor the numerous inscriptions[64] mention architects and/or engineers.

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[55] Feissel (1988); Feissel (2000) 92.

[56] Procop. *Pers.*, 2.30.5.

[57] Cfr. *PLRE*, III, 1314 (Thomas 2); Feissel (2000) 87.

[58] Ševčenko in Forsyth and Weitzmann (1965) 19–20.

[59] Feissel (2000) 87.

[60] McVey (1987).

[61] For other names of architects incidentally referred to in Early Byzantine literary sources, see Johnson *et al.* (1991); Anderson (1997).

[62] Frothingham (1894), Venditti (1967).

[63] Bernal Casasola (2004).

Some Considerations

The existence of this small group of *mechanikoi* in Justinian's service calls for some reflection. First of all, it is necessary to consider the real impact of this 'centralised' planning on Early Byzantine urbanism and architecture. In addition to the epigraphic and literary attestations, the phenomenon is also clear from the archaeological data. It is sufficient to compare, from the point of view of urban architecture, fortresses and new cities built by imperial *mechanikoi* on the basis of a centrally-devised plan (Dara in Mesopotamia, Zenobia-Halebiyye and Resafa-Sergiopolis in Syria)[65] with contemporary towns of roughly equivalent size, which lack any evidence for comparable planning, for example, the so-called new 'cities' of the Negev desert.[66] The first were solidly founded in the Hellenistic-Roman tradition, whereas the absence of any form of planning in the second case led to village-like communities, with messy conglomerations of buildings that were very reminiscent of the large villages of northern Syria.

From another perspective, the city-walls along the eastern frontier clearly confirm that large religious monuments were transformed into structures of a purely functional nature. The towers of Zenobia-Halebiyye, for instance, show a whole range of refined planning solutions that were applied by Isidorus the Younger and John of Byzantium in the capital:[67] reduced arch vaults, conic rampant vaults and intersections between rampant and horizontal barrel vaults.

Further, one has to acknowledge the close involvement of Justinian's *mechanikoi* in military engineering.[68] The people named in the sources essentially worked on the planning of new defences, or were engaged in urban repairs to fortified centres along the frontier. It seems probable that at least some of them fell directly under the military administration, as had been the case in the Roman world. This suggests that the army continued to play a fundamental role in building work; not only providing the major economic impetus behind construction projects, but also instigating the diffusion of urban and architectural designs, construction techniques and even building materials. In the provinces, for example, in northern Syria, one can thus find a combination of Constantinopolitan and local construction traditions.[69]

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[64] Durliat (1981).

[65] Zanini (2003).

[66] Shereshevski (1991).

[67] Lauffray (1983).

[68] On the close connection between *mechanikoi* and military engineering in Greco-Roman world, see Saglio (1904).

A third point concerns the cultural background of these planners. The term *mechanikos*, or *mechanopoios*,[70] which is sometimes placed side-by-side with, but often preferred to *architekton*, offers the first indication of their background and education, which seem to be ultimately related to the great Vitruvian tradition, referred to by Pappus Alexandrinus in the early 4th c.[71] According to Pappus Alexandrinus, a correct education in the field of 'mechanical science' (*mechanikè theoria*)[72] entailed two strands: one theoretical (geometry, arithmetic, astronomy and physics); and another practical (metallurgy, architectural construction, carpentry and pictorial art). Both were necessary to successfully face complex technical problems related to statics, orientation and exposure.[73]

When looking at the *mechanikoi*'s social status, it is remarkable that their names are recorded in literary and epigraphic sources directly linked to the imperial court, alongside the names of sovereigns and local governors. This implies their affiliation to a high social class. Early Byzantine architects—at least those charged with prestigious jobs—seem thus to have preserved the status of their Roman and Late Roman predecessors, the last often even holding senatorial rank.[74] For example, an epigraph from Chalcis states that Isidore of Miletus the Younger was, despite being at the start of his career, already honoured with the title of *illustris*.[75] It is, therefore, reasonable to assume that by the time he was summoned to the capital to reconstruct the dome of the Great Church, he had been decorated with the same honours as had his uncle, Isidore the Elder, and Anthemius of Tralles, some decades earlier.

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[69] Deichmann (1979).

[70] Procop. *Aed.* 2.1.24, 1.1.50, 2.3.2, 2.3.14, 2.8.25.

[71] Downey (1949); Cuomo (2000).

[72] *Pappi Alexandrini Collectionis libri quae supersunt* (ed. F. Hultsch, Berolini (1876–1878) 1022–24).

[73] Downey (1948).

[74] Lucas (1873); Saglio (1904); Gros (1983).

[75] Foudrin, Feissel (1994).

Finally, we must also broaden the picture, and wonder whether or not the educated, wealthy and celebrated architects at Justinian's court represented a striking 'anomaly'; the tip of the iceberg, who conveyed the most visible element of a strong technological tradition, which continued to be diffused in Early Byzantine architectural planning and building practice. On one hand, *mechanikoi* only appear in the 'élite' sources (classicising histories, treatises, panegyrics, and monumental epigraphy), in which they are obviously associated with the portrayal of emperors as 'Architects of the Empire'.[76] Moreover, their history seems to be tied up with the central decades of the 6th c., after which they disappear from the historical record: only one late inscription, dated to the last quarter of the 6th c., mentions an imperial *mechanikos* erecting a fortification in Anasartha, Syria.[77] On the other hand, there is a large amount of material evidence suggesting the existence of professionals possessing the theoretical, technological and practical knowledge required to design a building or urban settlement.

Engineers, Architects, Contractors

The best evidence of continuity in architectural and building techniques is once again literary and epigraphic, including texts belonging to less 'high-brow' genres, such as chronicles, hagiographical works and 'private' epigraphy. For example, the *Vitae* of Saint Simeon the Stylite, Saint Martha and Saint Nicholas of Sion[78] recall the impressive reputation of 6th c. master-builders from Isauria. One of them, Angoulas, appears to have been in charge of the erection of a church dedicated to Saint Martha. These Isaurian architects apparently fulfilled various tasks on construction sites, often situated far from their own region. Once more, epigraphic evidence is the most enlightening. The Syrian region of Belus possesses dozens of inscriptions publicly acknowledging specific artisans in charge of planning and constructing buildings of varying complexity.[79] These inscriptions are again evenly distributed over two centuries, from the second half of the 4th c. to the A.D. 560s. Therefore, this last decade seems to represent another break, if not in the continuity of construction theory, technology and practice, than at least in their public recognition.

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[76] Johnson, Loerke, Kazhdan (1991).

[77] Bowersock (2002).

[78] Magoulias (1976) 11–16.

[79] Butler (1929) 254–57; Tate (1991).

What is more, all of our sources refer to a variety of professionals, among which the *architekton* (mentioned four times, and seven as simply, *tekton*), and the *technites* (twenty occurrences) stand out. The distinction between these two roles is not very clear. Perhaps the terms were identical, since the attested *technites* seem to have dwelt mainly in the Belus region, while *archi(tektones)* are attested more regularly in central Syria. Further, they were engaged in similar activities—constructing private and public functional structures (houses, workshops, graves, churches)—and apparently possessed a similar, eminently practical, technical knowledge that, whilst not placing them at the highest levels of the social hierarchy, did grant them an elevated status, allowing them to publicly 'sign' their own work. The fact that only the *architekton* appears to have been endowed with a legal identity and a proper role in the public administration is a further indication that *technites* were present across the empire. *Novella* 7 of the Justinianic *Corpus Iuris*, for example, recommended the presence of one or two *insigni mechanici aut architecti* in the committees drawing up the *emphyteusis*, or long-term leases, of church holdings, where they were responsible for evaluating and correctly fixing the rents on plots of land. In a 6th c. text collected in the *Book of Ceremonies*,[80] an *architekton* is charged by the emperor with the official 'volumetric' measurement of the corn stored in the public granaries of Constantinople during an annual ceremony.[81]

On the whole, these professionals were probably less exceptional than the imperial *mechanikoi*, although they perhaps operated within a more limited working territory and had cruder skills. Nevertheless, these individuals could be responsible for all phases of a building project, from the planning and design, to the actual construction of a building, relying on inherited knowledge and imperial directives. Numerous examples of these experts appear in the Justinianic code. They are present in laws preserved from the Theodosian code,[82] and especially in the *Novellae*, which regulate the use of suitable building materials and the maximum height of and minimum distance between buildings, and are even concerned with protecting immaterial factors, such as the right of citizens to enjoy a sea view.[83] With this in mind, it thus becomes understandable that Julian of Askalon called himself '*architekton*'. Julian was the author of a sort of 'urban manual' based on common law in Palestine,[84] a mid- 6th c. booklet which offers an interesting perspective on the complexity of regulations—government edicts, local rules or customs—for the planning and erection of dwellings, shops and workshops in a contemporary city.[85]

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[80] *De caer.* 2.51 (ed. J. J. Reiske (Bonn 1829) vol. 1, 699–701).

[81] At the same juridical figure seems to be related those of the architect quoted in Gothic legislation as 'consultant' of the Roman *Praefectus urbi*: Cassiod. *Var.* 7.15 (*CSC*, XCVI, 274–6).

[82] *Cod. Just.*, 8.10 and 8.13; Baldini Lippolis (2005).

Epigraphic sources, in particular, distinguish—and in some cases contrast—the figure of the *architekton* and/or *technites*, from the *oikodomos*, who apparently, from time-to-time, took on the role of building contractor and/or that of master-builder. In both cases, this character seems to have been responsible for organising and managing a building site. He could direct and manage specialised artisans and different numbers of labourers throughout the entire building project—from selecting and preparing the raw materials, to processing them according to various building techniques, to the final decoration of a structure. The *oikodomoi*—frequently united in professional guilds, the nature and socio-economic status of which are depicted by the famous mid-5th c. inscription from Sardis[86]—appear to have been the true bearers of practical knowledge. This made them fundamental to the transmission of material culture between generations, since it was they who interpreted and passed on regional building traditions. Then again, they could frequently be compelled to apply the rules of a specific tradition to a project designed according to a new, or at least different, spatial scheme.

Material evidence for these trends can potentially be obtained through the study of construction patterns in a number of 'peripheral' regions of the empire. For instance, metrological analysis of some 6th c. churches in the 'cities' of the Negev desert (Southern Israel) has revealed that their measurements and proportions were clearly related to the Constantinopolitan tradition, even though they were erected according to traditional, indigenous building technologies.[87] The same compositional schemes—of course implemented with totally different techniques—seem to underlie the design of many contemporary religious buildings in Illyricum,[88] and sometimes in Palestine too.[89] This may again confirm the diffusion of theoretical, standardised models, developed into a communal culture of architectonic planning,[90] and adapted where necessary to varying local building traditions.[91]

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[83] Zanini (forthcoming).

[84] Saliou (1996).

[85] Saliou (1994; 2000).

[86] Sodini (1979); Di Branco (2000); Zanini (2005).

[87] Chen (1981; 1985); Milson (1989).

Since their work was basically practical and site-based, the *oikodomoi* operated in well-defined, sub-regional territories. However, we do possess some evidence for the long distance mobility of well-organised groups of specialised craftsmen, who originated in regions with ancient and well-established building traditions. The most obvious case is that of the Isaurian *oikodomoi*, whom many sources refer to as the most skilled master builders in the market, receiving exorbitant fees.[92] As seen above, Isaurians erected the great shrine of Saint Simeon the Stylite in northern Syria, and also carried out maintenance works on Hagia Sophia, both before and after its dome collapsed, and re-building work was carried out by Isidore the Younger.[93] The trans-regional mobility of Isaurian builders—and of their counterparts from regions with an equally strong tradition of monumental construction work (primarily Armenia and Syria)—again casts light on the complexity of the exchange of ideas, technologies and techniques relating to the art of construction in the Early Byzantine world.

We can, therefore, attribute continuity in urban design, architecture and infrastructure during Late Antiquity to the activity of imperial *mechanikoi* and architects working for urban communities. The images of luxury and 'polyphony' that are closely associated with architectural design and production in the eastern Mediterranean basin in the 5th and 6th centuries can be associated with the mobility of these people. Both of these elements are apparent in what is possibly the most emblematic archaeological site of the epoch: Caričin Grad—Justiniana Prima, founded by Justinian to honour his birthplace in northern Illyricum, after the region had returned to imperial control.

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[88] Underwood (1948); Spremo-Petrović N. (1971).

[89] Wilkinson (1981).

[90] Dufaÿ (1985).

[91] The Holy Cross Church at Resapha is a very rare example in the archaeological record of the operational procedures adopted to translate a project into a concrete building still evident today. On the floor of the nave, one can see several large semicircular carvings, clearly traces of the full-scale design of the centrings used to build the large, longitudinal arches between the aisles; Bayer (1986).

[92] Zanini (2005).

[93] Mango (1966). At least two passages of *De Bello Gothico* by Procopius demonstrate the brilliant reputation of these builders, who were frequently employed in military engineering projects. At Auximus, they were entrusted with the demolition of an ancient cistern (2.27), and during the siege of Naples, they were in charge of enlarging the aqueduct channel to allow the army to enter the city (1.9.18). According to this last episode, this entry-route was discovered by another Isaurian, who 'was seized with the desire to observe the construction of the aqueduct, and to discover in what manner it provided the supply of water of the city' (1.9.11; transl. H. B. Dewing (1953) 87).

An analysis of the urban grid of this site suggested that it was the result of the two-fold process mentioned above.[94] A first phase very probably took place at Constantinople, following the same procedure as in the case of Dara: the drawing up of a general plan in which classical urban designs were adapted to the unusual topography of the area in question. The second phase was executed directly on site, leading to the clear alteration of the main axes of the city in order to adjust the 'theoretical' plan to the topography of the site. Afterwards, monuments that were fundamental to this kind of city—according to the model of an 'ideal' city—[95] were erected within the urban framework. They included several churches, city walls, baths, porticoes and other secular complexes, all constructed contemporarily, with the same building techniques and, it may be assumed, by the same builders.

It is possible that these workers were local or regional, attracted by the economic and fiscal benefits habitually offered to those involved in such projects. However, more experienced, possibly itinerant builders, following the army, may have also worked on the site. An examination of the building technique adopted supports the second hypothesis. It consists of a revised version of the traditional Constantinopolitan practice of alternating stones and bricks, replacing the limestone with large pieces of local schist. This technique was frequently used in Early Byzantine *castra* on the banks of the Danube.[96]

At the same time, however, a number of styles are evident in the different buildings. For instance, the large Episcopal basilica on the acropolis presents an interesting example of a building with a 'Greek' plan and Constantinopolitan features. There are comparable examples in Bulgaria. The large 'transept basilica' in the lower city also displays Greek architectonic features, while the two churches located just below the acropolis were clearly influenced by 5th to 6th c. Constantinopolitan architecture. Three smaller churches, situated inside and outside of the city, exhibit regional architectural trends.[97]

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[94] Vasić (1990).

[95] Saradi (1995).

[96] On brick production directly linked with the military administration of the river Danube, see Sodini (1979) 73–75.

This architectonic variety can only be explained if planners and workers from a variety of provinces had been present on the building site at the same time. The city planners probably came from Constantinople, the masons must have been local, or members of the army: the architects and the *oikodomoi*, who were in charge of planning and erecting the churches, came from the capital, Greece, and central and eastern Illyricum. They all worked together on a site that, from the perspective of urban planning, was uniform, even if the architectural development of its different buildings owed more to a variety of styles and influences. In other words, in order to create the seat of the new *praefectura*, bearing the name of the emperor and conceived of as an 'emblem' of the imperial capital, they created a smaller-scale model of the building site that was laid out exactly two hundred years earlier, when Constantine re-founded Byzantium.

Centre vs. Periphery—Byzantium vs. the Others

Now that we have used literary sources and archaeology to demonstrate the mobility of people and architectural technologies and practices, two further questions remain to be answered. First of all, we still need to evaluate whether this phenomenon merely concerned technical-organisational aspects, or whether it influenced the development of 'high' architectural culture in a more profound way. Secondly, we need to clarify whether it had an impact outside of the Early Byzantine Empire, in the Early Islamic or West Mediterranean worlds. These problems relate to not only the practical application of technical and technological solutions by travelling architects and master builders, but to the more abstract diffusion of models, designs and formalised techniques. To investigate the premises and mechanisms of such a dissemination of styles and ideas, archaeology must join forces with architectural history, which studies more closely the manner in which ideas can circulate.

A first issue concerns the dichotomy between centre and periphery. According to an abstract model, the relation was unbalanced in favour of the centre, where resources made available by richer and more articulated patronage networks (whether ecclesiastical, economic, social, military, aristocratic...) generated new ideas, which were then diffused throughout peripheral regions, normally in a limited way. This abstract model may only be applicable to the Roman world, which possessed a remarkably strong centre. Rome was able to export its ideas, to a certain extent as serial products, to the most distant regions. However, the model seems less fitting in the case of the polycentric 6th c. empire. Co-existing, propulsive centres, not necessarily located in large towns, played an important role in developing the 'multi-vocality' so apparent in the architectonic production of the 5th to 7th centuries.[98]

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[97] Duval (1984) 444–52.

For example, the domed church with ambulatory has long been considered to be one of the most spectacular Justinianic innovations in Constantinopolitan architecture, and the model for churches such as Saint Sergius and Bacchus, Saint Eirene, and even Hagia Sophia. But a recent, stimulating study has now demonstrated that it was not the extraordinary 'creation' of the court *mechanikoi* inspired by the emperor himself. Instead, it seems to have been the result of an extraordinary 'application' of designs, spatial schemes and technical building solutions clearly attested in Isaurian architecture from the 5th c. which, boosted by imperial patronage, were applied on a more monumental scale.[99]

The circulation of designs and technology during the 6th c. was thus booming, as men from peripheral regions with long-lasting construction traditions—Isauria, Armenia, Syria, Egypt and Greece—acquainted with building technology and good practice were drawn to the new focal point of the late antique Mediterranean, where large economic resources were available.[100] The blending of the technological and practical expertise of the *oikodomoi* and the theoretical knowledge of the *mechanikoi* created the 'cultural climate' in which new designs and new building procedures were devised, and out of which the great era of 6th c. Constantinopolitan architecture developed. In the same crucial period, the need to re-organise the infrastructure and monuments of the re-conquered provinces created a virtually endless scope for the application of such ideas and technological innovations. Considered in this light, the monumental remains of the Early Byzantine *grand siècle* become vital pieces of evidence, heightening our understanding of the origins of this technological culture, and its progressive synthesis of a theoretical background inherited from Antiquity and a plurality of regional traditions.

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[98] Mango (1978) 7–17.

[99] Iacobini (2003–2004).

[100] The phenomenon is attested until the age of Constantine V, who recalled *technites* and *oikodomoi* from all over the empire to complete the restoration of the Valens' acqueduct (Lopez (1959) 79).

Moreover, this culture tended to be 'exported'; directly to the Early Islamic world, for which Early Byzantine urbanism, architecture and building practices provided the models on which cities,[101] infrastructure and monuments[102] were based.[103] The less direct, but equally obvious impact of this culture on the West should also be noted. Here, the perpetuation of Byzantine building traditions, in some regions at least, provided one of the foundations of the re-birth of building technology in the Middle Ages.[104]

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[101] Hillebrand (1999).

[102] A precious witness of the complex transformation of the connection between Byzantine and Arab architectonic culture is well represented by the building of the Palace of Bryas, in Constantinople's *suburbium*. Here, in the 9th century, an architect Patrikes is instructed by his patron to build a palace directly inspired by the Arabian palaces of Syria.

[103] Arce, in this volume.

[104] Kleinbauer (1988).

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THE ART OF BUILDING IN MILAN DURING LATE ANTIQUITY: SAN LORENZO MAGGIORE

Laura Fieni

Abstract

This study of the complex of San Lorenzo in Milan draws on archaeological and archaeometric evidence. It presents the results of a recent investigation into late antique masonry techniques at San Lorenzo, which looked at stone and brick masonry techniques, the various type of foundation systems and the building techniques responsible for the structure as a whole. The archaeological element of the paper is based on a stratigraphical analysis of the entire complex, including its stone foundations, pavements, brickwork, vaulting and plasterwork; research on bricklaying, stone-cutting and masonry techniques; and the dating of its windows, doors, and frames. At the same time, the archaeometric aspect of the paper comprises the typological categorisation of the building materials identified at the site. These include stones, bricks, and the ingredients of bonding sections, mortar work and plastering. The origins and dating of these materials will also be an important part of the paper. Dating was carried out using TL and ^{14}C methods.

The basilica of San Lorenzo in Milan comprises a series of chapels, towers, domes, and reconstructed wings that have been added to a building initially founded in Late Antiquity, mainly during the Early and Late Medieval periods (fig. 1). Two principal problems have plagued archaeological research on the structure during the 19th and 20th centuries: the chronology of its foundation, and the identity of its initial patron. These problems are the result of a lack of documentary sources referring to the complex and its tetraconch plan. The uncertainty concerning its foundation has resulted in a variety of hypotheses.[1] These range from speculative suggestions that the building had initially operated as a pagan temple or *thermae*, to more realistic arguments that it was a 4th c. Christian foundation, during the age of either Constantine

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[1] Calderini (1934) 61–180.

L. Lavan, E. Zanini, and A. Sarantis (edd.) *Technology in Transition A.D. 300–650*
(Late Antique Archaeology 4 – 2006) (Leiden 2007), pp. 407–433

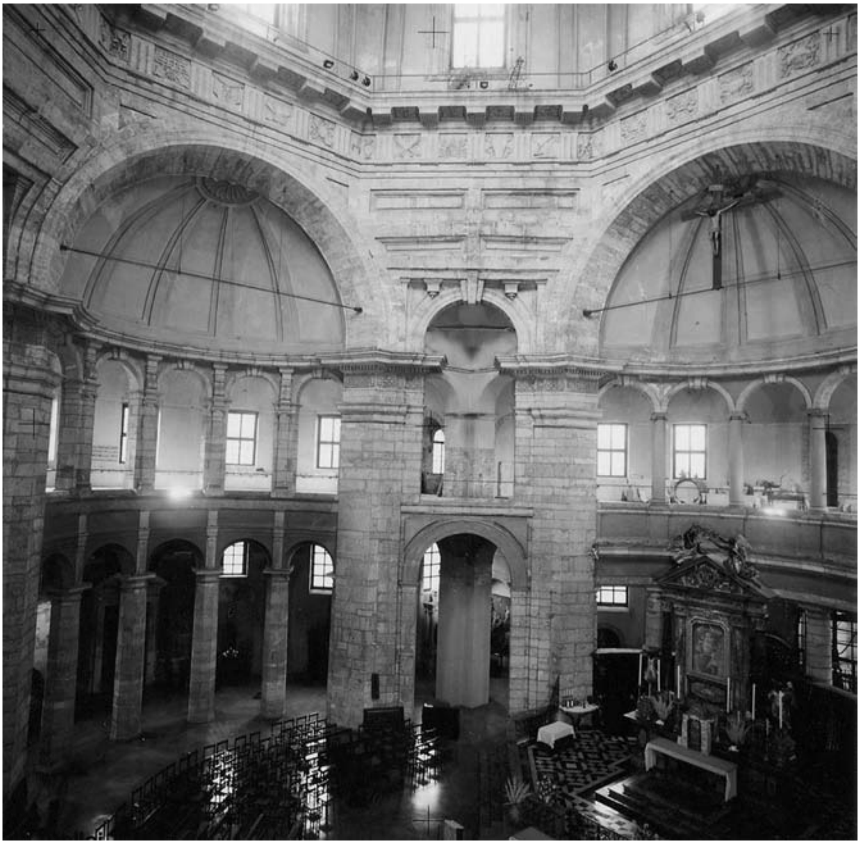

Fig. 1a Interior of San Lorenzo, Milan

or Ambrose, or a 4th to 5th c. construction, during the era of Stilicho and Galla Placidia.[2]

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[2] Fieni (2004a) 179–81. R. Krautheimer at first ascribed the building to the pre-Ambrosian period, suggesting that its patron had been the Arian bishop, Auxentius (A.D. 355–374), but later, on the basis of work by Kinney and Kleinbauer, he argued that it was founded much later, as Chierici had already done in the mid-20th c. and identified San Lorenzo with the legendary *basilica Porziana* over which Ambrose and the Arian Court quarreled between A.D. 378 and A.D. 386. Meanwhile, Ruffolo, agreeing with Mirabella Roberti, proposed a later data, of about A.D. 390. S. Lewis has been the strongest exponent of a Theodosian date, arguing that it had functioned as a Palace church. On the basis of liturgical sources, Cattaneo placed the foundation of San Lorenzo even later, at the beginning of the 5th c. and attributed it to the General Stilicho. See: Krautheimer (1986) 88–90; Chierici (1951) 180–82; Kinney (1972) and

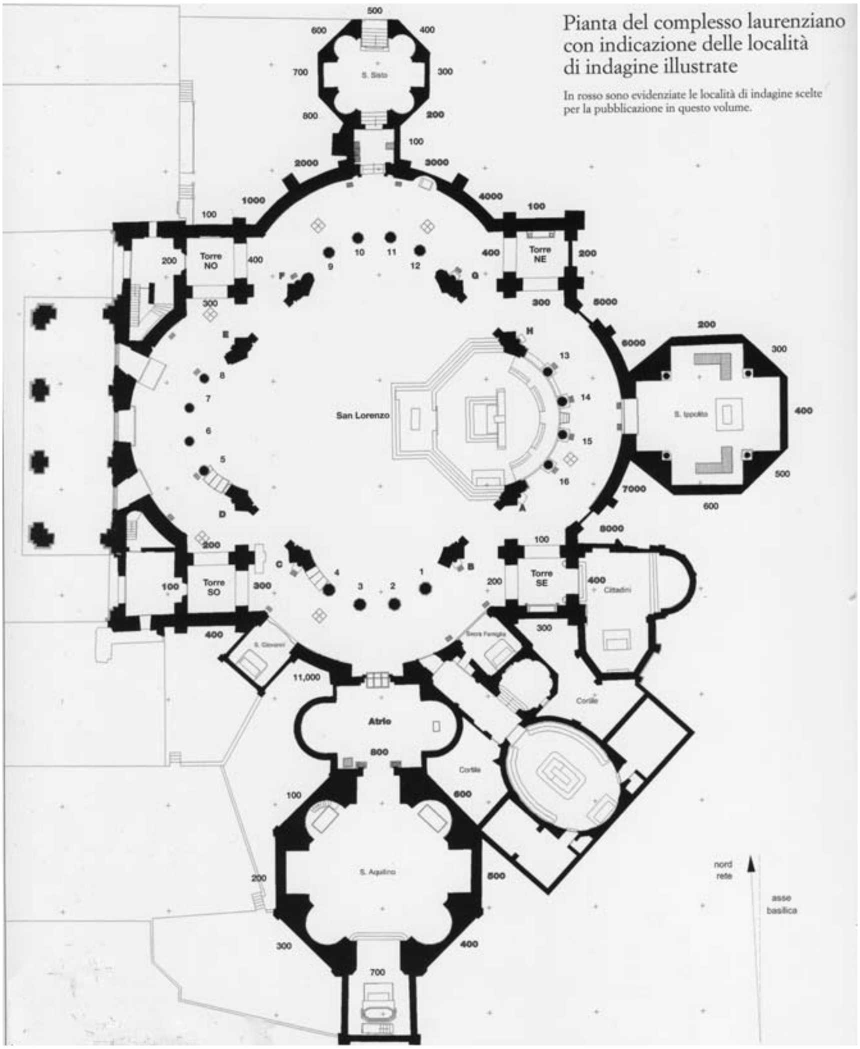

Fig. 1b The San Lorenzo complex in Milan, plan.

The archaeological remains of the complex have been severely affected by a series of careless repairs; from the Neoclassical age to the restorations carried out by A. Annoni in 1912–1913, and by G. Chierici

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(1987); Kleinbauer (1968); Krautheimer (1987) 129–48; Ruffolo (1972) 49–52; Lewis (1973); Cattaneo (1985) 17–37.

between 1935 and 1942, which destroyed, respectively, the archaeological deposits of the chapel of Saint Aquiline and of the rest of the complex. Finally, the urban development around the site completed the destruction of the archaeological stratigraphy.

This paper presents the results of stratigraphic and archaeometric surveys of the entire monument. Every effort has been made during these surveys to define precisely its building phases, and identify the building materials used in its various structures. Archaeological studies of the basilica have previously focused on the masonry techniques used, with a special interest in the bricks. They have used a variety of approaches to date the work of craftsmen on the complex. These approaches include, for instance, an abstract theory concerning late antique masonry techniques in Mediolanum, which has encouraged speculation as to the metrological characteristics of the bricks used and the parameters of the masonry. Survey methods have inevitably resulted in very different and sometimes contradictory results. This article will discuss the results of an analysis of the site that has focused on the technological characteristics of the building. Technical data represents an invaluable source of information regarding not merely the design of the church, but also the chronology of its erection. Indeed, modern 'architectural' archaeology has taught us that, from a methodological perspective, it is vital to focus both on chronology, as well as architecture.

Our stratigraphic study of the walls has generated a series of important discoveries about the building techniques used in the basilica, and the phases during which these were used, employing a variety of dating methods, such as radiocarbon and thermoluminiscence, that allow us to go beyond traditional inductive approaches.[3] In general terms, the different styles of the building can be associated with different chronological phases. The study of the masonry of the basilica has never been based on a stratigraphic approach, but on a few passages in literary sources which happen to correlate the impression given by the material remains of masonry work. As my article will now show, this approach has deeply influenced the dating and technological analysis of the building materials employed in Milanese late antique architecture.[4] Generally speaking, this is a method more suited to the study of classical Roman architecture, and which is not necessarily applicable to the buildings of later periods.

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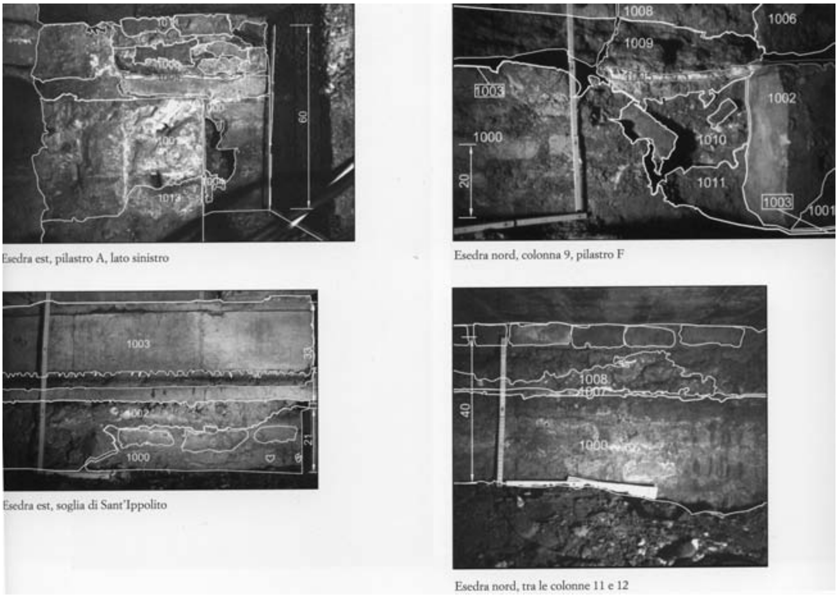
[3] On *Mediolanum* masonry techniques see Ruffolo (1972).

[4] Specifically for S. Lorenzo see Kleinbauer (1968); Kinney (1972).



Esedra est, pilastro A, lato sinistro

Esedra nord, colonna 9, pilastro F

Esedra est, soglia di Sant'Ippolito

Esedra nord, tra le colonne 11 e 12

Fig. 2 Stratigraphic survey: pavement level near pillar A; between column 9 and pillar F; under the entrance to the Chapel of Hippolytus; between columns 12 and 13.

Our stratigraphic survey was applied to entire building structures and to the hypogea, foundations and floor levels (fig. 2–3). It involved the rigorous application of archaeometric dating methods to the masonry, with the aim of identifying five late antique building phases according to the techniques observed. Absolute dating established that the complex was founded between the reigns of Theodosius I and Honorius, when the tetraconch heart of the complex, the towers and the chapel of Saint Hippolytus (phase I) were built. This phase was quite immediately followed by the building of the chapel of Saint Aquiline (phase II), where the chapel of Saint Sixtus (phase III) was built in the first half of the 6th c.[5] Slightly more recent were the gallery in the chapel of Saint Aquiline (phase IV), and a large window on the north-eastern side of the same chapel (phase V), probably dating to the Early Lombard era.[6] This dating demonstrates that a late antique building technique, based on the use of brick, continued until the Lombard era.

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[5] Fieni (2002) and (2004, a–b); Fieni *et al.* (2005).

[6] Fieni (2004d) 253–55.

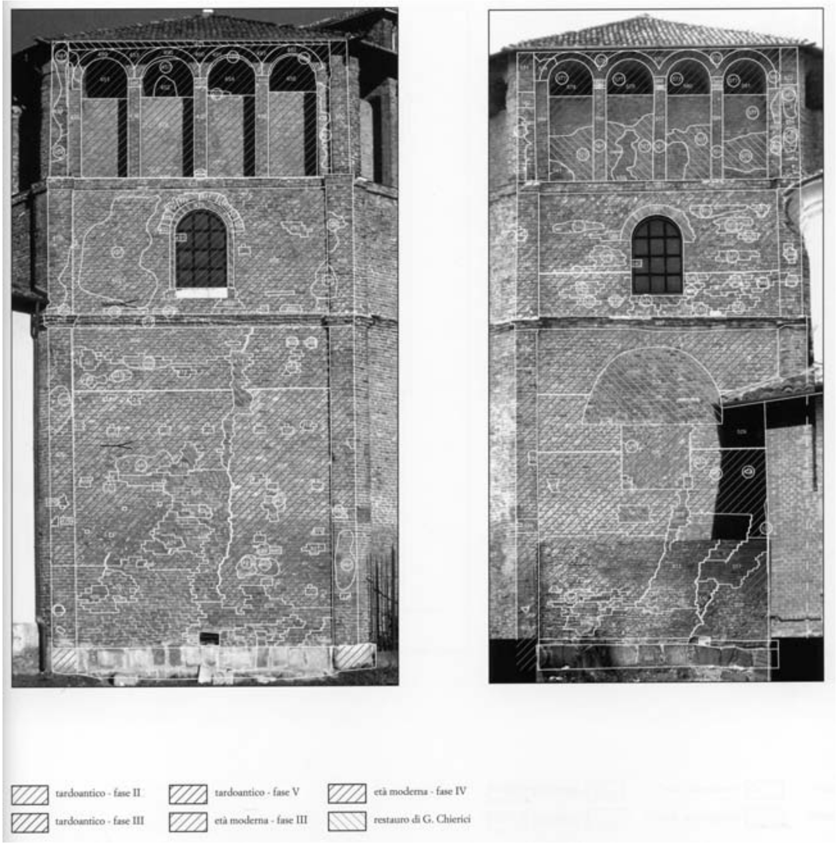

Fig. 3 Stratigraphic survey: Chapel of St. Aquiline, east facade.

Meanwhile, we attempted to produce a technological analysis of the stone foundations, which were the subject of the first archaeological surveys in the early 20th c. Unlike previous researchers, we did not begin with the assumption—never scientifically proved—that the stones used were *spolia* from the nearby arena dedicated to the *Ludi gladiatorii.* An acceptance of this view would naturally influence any dating of the basilica. Nonetheless, the study of the brickwork of the San Lorenzo complex does cast light upon building practices involving the use of *spolia*.[7] In

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[7] Fieni (2002).

San Lorenzo, the *spolia* were, in some cases, ornamental objects, such as precious marble columns and capitals, and in others, raw materials such as brick, which had little value, but were fundamental to building work in Late Antiquity and subsequent eras. On two occasions, Roman materials were re-used in the building, both after the collapse of the dome and the two towers, first, in the Medieval period and later, in the Late Renaissance period. In this way, building materials can be used to date the various building phases, during which they were sometimes totally re-worked. Only by adopting a rigid stratigraphic methodology has it been possible to accurately identify the parts definitely belonging to the original structure, and so to avoid the application of thermoluminescence dating to Middle Age or Renaissance restorations, built with recycled fragments of Roman bricks.

Foundations

The stone foundations of the church were, generally speaking, set down in two ways. According to modern terminology, the original building, consisting of a tetraconch plan, four towers and the chapel of Saint Hippolytus, was founded on a 'continuous type' system—later also adopted during the construction of the two apsidal halls. Meanwhile, the chapel of Saint Aquiline was founded on a 'pit' system. The foundations of the chapel of Saint Sixtus are well-known thanks to the work of G. Chierici, who classified them as an example of the 'continuous' system. The great depth of the foundations, between 4 and 4.4 m, stems from the fact that the buildings were set on filling material. Therefore, the morphology of the site is artificial: 8 m above an ancient cobblestone street, on a little hill south of the city walls. To establish firm foundations on loose, possibly marshy ground, wooden piles were laid over the entire area upon which the building was erected. Above this wooden base, a layer of *cocciopesto* was inserted, upon which stone blocks were placed in turn. This movement of large quantities of earth is not uncommon in the history of Roman architecture; the construction of the church of St. Peter's on the Vatican Hill being perhaps the best example.

The tetraconch structure, defined as a *double shell*,[8] was constructed through the placement of brick walls on a double perimeter of partially sculpted stone blocks: one supporting the perimeter walls; the other, the columns and internal pillars. Loose material derived from the excavation work, including lime mortar casts and a variety of other ingredients, some originating in the ruins of other buildings, was cast into the gap between the two perimeter walls.[9] The upper section of the foundations, upon which the walls or pillars were founded, was put in place during a second phase. It was 1.5 m thick and comprised three layers of stone blocks. Gaps and cracks between the often irregularly shaped stone blocks were filled in with brick. This rendered the three layers of stone both solid and stable. The filling material tipped into the space between the two masonry curtain walls of the tetraconch structure was further compressed by small, radial stone walls (fig. 4).

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[8] Krautheimer (1986) 90.

The chapel of Saint Aquiline is built on a clay bank, overhanging towards the east. J. Kohte and A. Annoni carried out the initial excavation of the large platform, which was constructed from five layers of sculpted and moulded stone blocks (fig. 5), incorporating fragments of entablature, capitals, and dihedral capitals.[10] Pieces of brick and a cocciopesto mortar were used to seal the gaps between the blocks. A layer of square, granodiorite pieces standing to a height of two Roman feet are still visible.[11] This operated as a platform on which the brick walls of the octagonal chapel were erected.

Chierici's description is all we have for the northern apsidal hall.[12] He relates that a masonry technique similar to the *emplecton* was used in the structure. This Graeco-Byzantine technique involved setting bricks diagonally, rather than putting down parallel layers of bricks and joining them with cement. It would appear to have been unique to both the complex of San Lorenzo and to the city of Milan in general.

The foundations of the chapel of Saint Sixtus are visible from just outside of the structure. Where documentary evidence is concerned, we are once again reliant upon Chierici's[13] description. The ground underneath the chapel, which was composed of gravel and silt, was strengthened with wooden studs, on which 50 cm of mortar, and above

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[9] Artefacts found during the last archeological excavation to be allowed by the church were retrieved from this part of the foundations. See Rossignani (1990b) 148.

[10] The excavation technique adopted by Annoni and De Marchi was that of clearance, which led to the complete loss of a cemetery that had been set between the ground floor and the stone blocks. The latter were partially displaced in order to arrange the museum setting, altered by Chierici during his restorations in the 1930s and 1940s.

[11] One Roman foot is the equivalent of 29.7 cm: Adam (1994) 159.

[12] Chierici (1951) 76.

[13] Chierici (1951) 79.

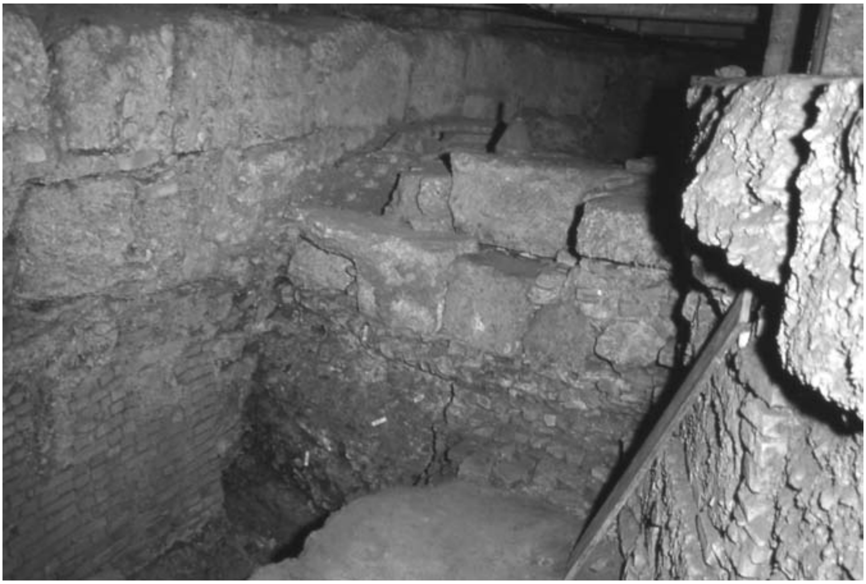

Fig. 4 Remains of archaeological deposits near the foundations of the western exaedra.

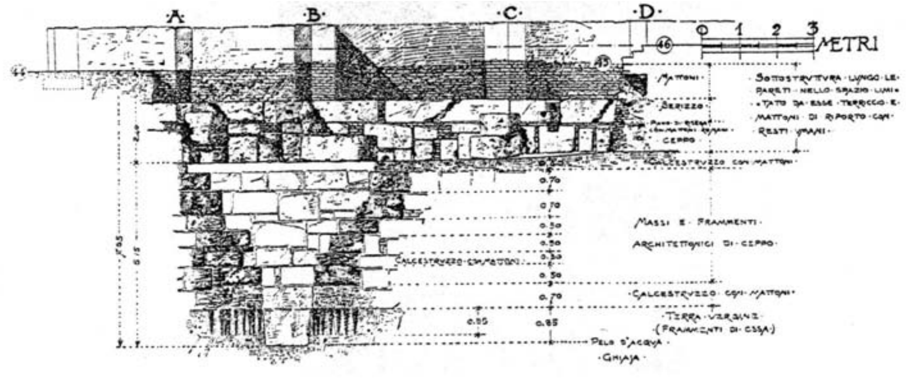
·A·
·B·
·C·
·D·
0 1 2 3 METRI
46
45
44
·MATTONI·
·SERIZZO·
·CEPPO·
·SOTTOSTRUTTURA·LUNGO·LE·PARETI·NELLO·SPAZIO·LIMI·TATO·DA·ESSE·TERRICCO·E·MATTONI·DI·RIPORTO·CON·RESTI·UMANI·
·CALCESTRUZZO·CON·MATTONI·
0.70
0.70
0.30
0.30
0.30
0.50
0.70
0.85
0.85
·MASSI·E·FRAMMENTI·ARCHITETTONICI·DI·CEPPO·
CALCESTRUZZO·CON·MATTONI
·CALCESTRUZZO·CON·MATTONI·
·TERRA·VERGINE·
(FRAMMENTI·DI·OSSA·)
PELO·D'ACQUA·
·GHIAJA·
2.40
6.15
7.55

Fig. 5 Excavation section into the large platform under the Chapel of St Aquiline, carried out by J. Kohte and A. Annoni (after Annoni 1913).

this a layer of *cocciopesto*, was laid. Subsequently, the real foundations were placed on top of these layers to form a 'continuous system'.

In general, two types of stone were employed in the complex: Lombard *ceppo*, which was a mixture of carbon-based materials that were quarried along the Adda; and the *sarizzo*, which was a quartz-feldspathic stone of magmatic origin. The latter is now principally quarried near Sondrio, in Val Masino, but in Antiquity was also found in northern Lombardy, as erratic boulders. It has been argued that these stone blocks were *spolia*. In the 20th c., archaeologists asserted that they originated from the Arena, an argument that has influenced the dating of the tetraconch structure and the chapel of Saint Aquiline. In contrast, our technological analysis of the site set out to refute this argument. First of all, we aimed to state whether building materials came directly from quarries or derived from erratic boulders, by examining lithology, dimensions and assemblages in the building technique. We based our typological categorisation of the stones on their shape; whether they were prism-shaped or moulded, and measured them using the Roman metric system, within which one foot is the equivalent of 29.7 cm.

The results of this research have cast light on some important technical points relating to the phases of the building. Different materials were used in the tetraconch structure and the chapel of Saint Hippolytus on the one hand, and in the chapel of Saint Aquiline on the other. The former were nearly all *ceppo*, and only included a small number of moulded and sculpted pieces (fragments of frames and capitals); less than 10 per cent of the stone. Samples of both stone types were present in this phase. Finally, the sizes of the pieces of stone cannot be rounded up or down to the Roman foot. Indeed, their parallel-piped shape suggests that they were not accurately cut, but roughly hewn, and in some cases splintered. In contrast, in the remains of the chapel of Saint Aquiline, equal quantities of the two main stone types are present, and the sculpted elements here are predominantly made from granodiorite, where the pieces of stone were juxtaposed with one another to create an entablature. Meanwhile, the capitals and the blocks, were made from *ceppo*, with sculpted decorations on one side. Finally, the cut entablature stones were irregularly set, with their sculpted side placed along the internal perimeter wall of the octagonal chapel.

The stonework in the apsidal hall displays the use of similar building materials and techniques to that located in the tetragonal structure. In this case, the stones not only differed in their placement, but in their measurement. Indeed, they varied greatly in shape and size. However, the irregular size and shape of the parallel-piped pieces of stone does

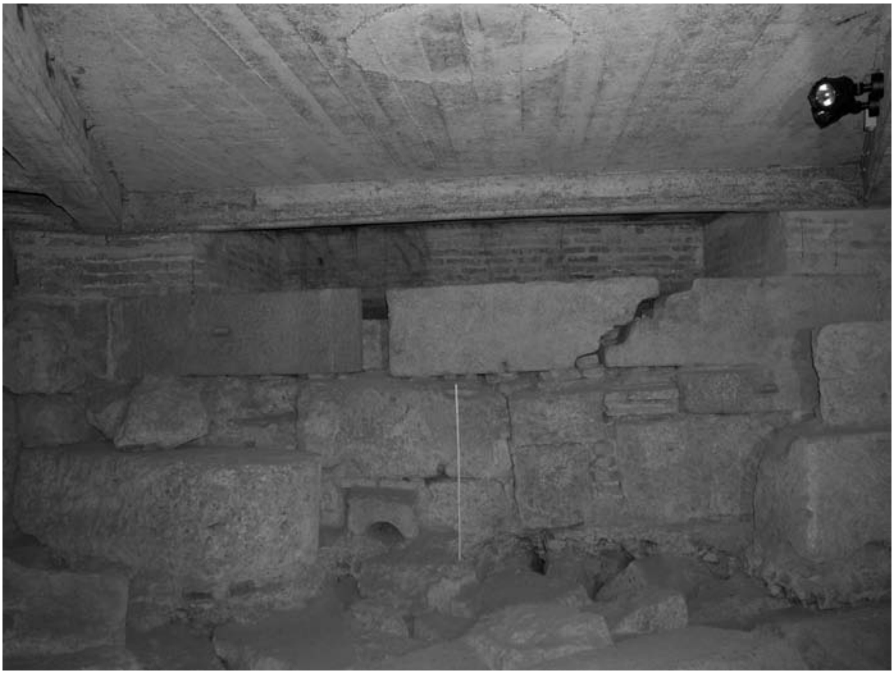

Fig. 6 Stone re-used in foundations walls.

not suggest that they derived from the ruins of one particular square-shaped building such as the Arena. Pieces of brick inserted between the cut stones and thick *cocciopesto* mortar work were, in all probability, intended to make the stonework straight and accurate. In fact, it is the whole pieces of stone that are more likely to have originated in the ruined shell of an earlier building. These are, in the majority of cases, granodiorite stones in the chapel of Saint Aquiline. The other pieces of stone apparently originated in a variety of places, including demolished buildings, and had been possibly collected and broken down in specialised brick making yards. This is suggested by their obviously small and irregular size, and the peculiar position of the holes drilled into them, which were intended to accommodate the olive-shaped wedges necessary for lifting the structure. The increasing variety in the size of the stone blocks used in the later building phases demonstrates that, as time went by, it became much harder for stone-cutters, builders and masons to handpick whole pieces of stone that were uniform in size, from specific sites (fig. 7). The same phenomenon is also apparent in the brickwork.

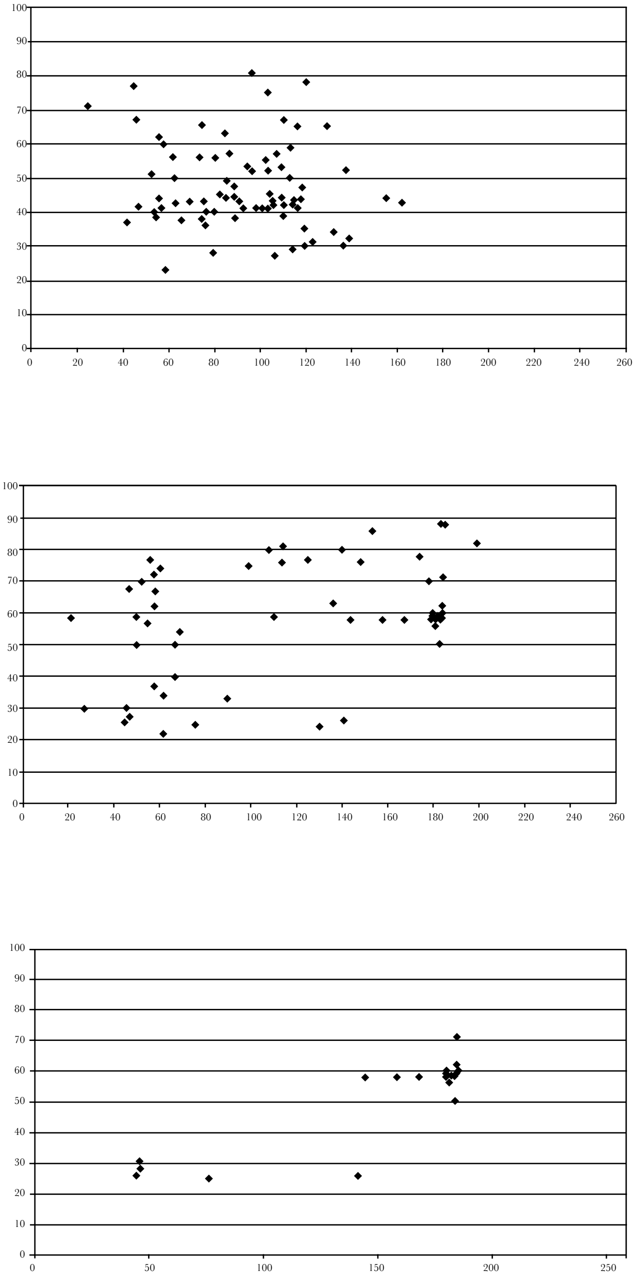

Fig. 7 Lengths of stone blocks re-used in foundation walls.

Bricklaying

The bricks were laid according to a technique that was typical of Late Antiquity, and which bears no relation to the techniques described by Vitruvius. It involved the use of a variety of bricks, in some cases whole, in others broken. These were essentially set flat and held together by vertical joints, which were more or less offset and very high, horizontal mortar joints, usually of 3–5 cm. A masonry technique which originated in the *opus testaceum* of the classical period[14] was applied to the external sections of the masonry, whilst the internal sections were always made from *opus caementicium*; a lime conglomerate with a variety of ingredients, including gravel, sand, cobblestone and fragments of ceramic, brick and tile (fig. 8a).

The whole bricks in the curtain of the masonry were generally of two lengths; 1 and 1.5 Roman feet, or 29.7 and 44.4 cm, never varying from these measurements by more than 10 per cent. These measurements correspond with those of both the most common bricks produced in late antique *Mediolanum:* the *sesquipedale provinciale*—a brick of 1 × 1.5 feet (29.6 × 44.4 cm); and a brick usually named the *sesquipedale bessale*, which habitually measured 1.5 × 1.5 feet (44.4 × 44.4 cm). There are no exact criteria for determining whether or not these bricks belonged to one of these brick types. Meanwhile, an entire brick of the *bipedale* type has been retrieved from the north-east tower. This measured 2 × 2 feet (59.2 × 59.2 cm).

According to our first archaeometric analysis, the bricks were mostly produced locally and made from fluvial clay. At a macroscopic level, the bricks' surfaces vary greatly in their colour, which ranges from dark red to pale yellow, in relation to the presence of 'Fe-Mn' oxides and inclusions of sand. These discrepancies originate in a variety of brick making procedures, some using a mixture of two different soils, others just one.[15]

The larger bricks evident in the archaeological remains could not have been lifted by just one man, and had perhaps been installed by two slaves. Therefore, it is possible that the stones were cut into established, pre-defined shapes after they were baked. However, Chierici discovered bricks of the *sesquipedale provinciale* type in complete pieces, thereby suggesting that these were baked in their final form. Our dating using thermoluminescense method has demonstrated that the same types of bricks continued to be manufactured until the end of the Lombard period.

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[14] Lugli (1957) 528–630. O*pus testaceum* was constructed with whole, baked bricks.

[15] Capelli (2004) 237–54.

From a technical point of view, it is important to understand how materials were accumulated and managed on the building site during the construction phase, bearing in mind that bricklaying is a rational operation to be carried out according to specific rules. Where possible, we measured the lengths and thicknesses of the bricks present in the various stratigraphic units on order to identify the morphological characteristic of the bricks used in the principal late antique building phases. This survey showed us that, in the first building phase (of the tetraconch), bricks of different measurement were used in different elements, such as pillars, exedras and towers.

By plotting the frequency distribution of brick dimensions into each stratigraphic unit, were were able to identify the most common dimension classes, and the minimum measurements of the bricks, beyond which it was no longer possible to employ the same building techniques. We were also able to identify the ratio of complete to broken bricks, and their most frequent thickness. Our investigation looked at both overall trends in brick size and shape, and trends specific to the various categories. Its most significant conclusions were as follows:

1) Whole bricks, of both one and one and a half Roman feet, are not present in large numbers in the brickwork of the complex, and are even less obvious in later building phases.
2) Only a fraction of the bricks, 5 to 7 per cent of the total retrieved, were actually new bricks, produced during building phases I (tetraconch structure) and II (the chapel of Saint Aquiline).
3) The minimum length of the bricks used in the initial construction was 8 cm.
4) The course of the polymodal curves tends to move towards the left in the more recent masonry, showing that over time, smaller bricks were used in larger numbers, and larger bricks were harder to find.
5) The production of new bricks did not stop in Late Antiquity, although fewer bricks were manufactured than in earlier times.
6) The thickness of the bricks does not relate to their chronology.
7) Several measurements tend to come close to multiples and submultiples of the Roman foot (fig. 8b).

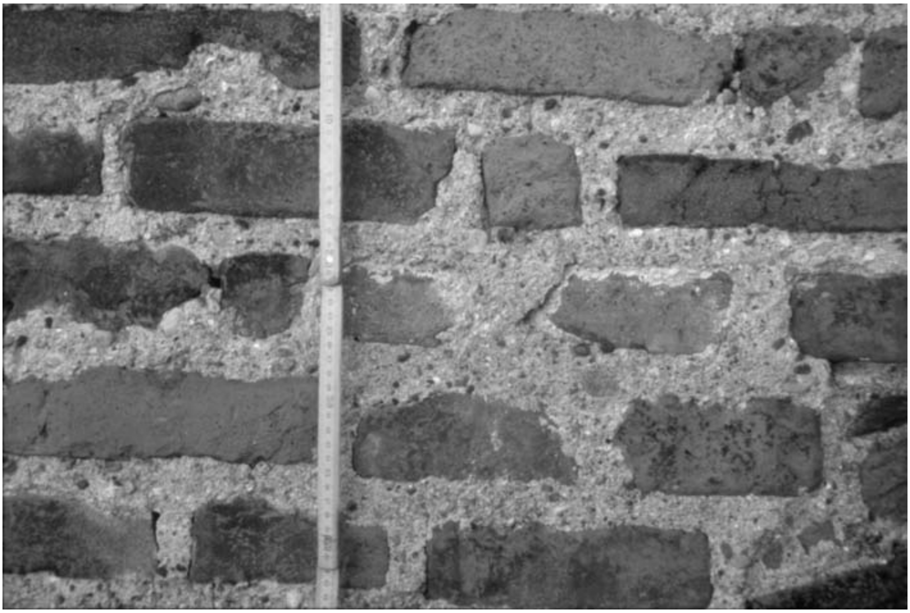

Fig. 8a External facing of late antique masonry of the tetraconch (phase 1).

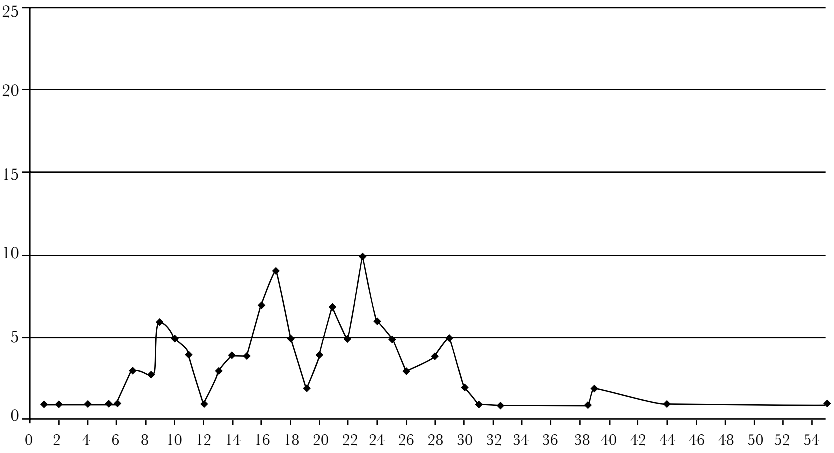

Fig. 8b Frequency of the width of bricks in the late antique masonry of the tetraconch.

Therefore, it may be surmised that the bricks were brought to the yard, divided into groups according to their length, and chosen by the workmen according to the masonry technique they were using and the materials available. The bricks were then cleaned of mortar and, where necessary, hewn into rectangular shape. It is impossible to know for certain whether or not the bricks were cut according to any pre-defined brick types, which were measurable by the Roman foot. Nevertheless, from research in this area to date, it would appear that the tendency was to cut the sides of the bricks roughly and quickly, thereby ensuring the smoothness of the walls. The thickness of both the horizontal and vertical mortar joints compensated for any irregularities in the shapes of the bricks—especially on their vertical side—and the significant differences in their girth. Marks left by instruments on the external facing of the bricks show that the plastering in these areas was levelled with considerable precision. Further traces of the builders' activities point to their use of specific instruments for the working of the stone, such as chisels and small hammers. It seems that levelling operations, probably carried out using flat-tip chisels, were closely related to the cleaning of old mortar from the bricks—for which it seems that tip and claw chisels were employed. Because the tools in question varied in their shape and dimensions, it is impossible to tell whether there was any kind of technical specialisation.

As has already been argued, the accuracy with which the bricks were laid varied greatly but, in general, seems to have progressively decreased from the original construction work through to the most recent. Further, the texture of the walls became less uniform, a trend which may be at least in part attributed to the decreasing length of the bricks being used. In the later phases, fragments of stone and, in a few cases, rare fluvial cobblestones are present in the masonry work.

Technological Details

The technological solutions reached in the Laurentian complex were determined by the extent to which standardised building techniques and procedures existed. They also depended to a great extent on the availability of complete bricks, and the existence of a pre-defined typology of brick manufacture and use, founded on the classical building tradition.[16] Entire bricks were employed in bases supporting pillars, and were also intended to hold up the arches passing between them and the exedras. They were also used in the portals and around the windows; in the external dihedral buttress within the chapel of Saint Aquiline; in the horizontal frames surrounding the tetraconch structure; and in the tower and chapel of Saint Aquiline.

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[16] Adam (1994) 159.

The pillars were erected according to an architectural solution that used complete or halved *sesquipedali provinciali*, laid alternately to guarantee their robustness. In contrast, all of the arches, including those of great width, were constructed from bricks radiating concentrically from their centre, which were, in turn, secured by wedge-shaped joints made from *cocciopesto* mortar. The great length of these joints meant that the thick masonry could be overlaid with just one layer of brick. This ensured the greater durability of the structure.

Late antique building technology was innovative in its ability to deploy a variety of recycled materials in structures whilst, at the same time, ensuring their aesthetic beauty. The same technological solution was applied in the octagonal Ambrosian baptistery of Saint John,[17] a building some years older than the chapel of Saint Aquiline, using the few complete bricks available to build up the faces of the walls.

Mortars and Plasters

The use of mortar in the joints is another important characteristic of late antique masonry work. The considerable thickness of the masonry in the Laurentian complex is typical of other late antique Milanese buildings. Our superficial quantitative analysis of the building materials retrieved has thrown up a ratio of 55–44% of bricks to mortar, thereby showing that both were generally used in equal measure. The considerable thickness of the joints certainly allowed master builders or architects to limit the amount of brick they had to use. In fact, in comparison to modern walls, the late antique walls of the Laurentian complex incorporated around 20 per cent less brick. Archaeometric surveys of the late antique mortar bonds show that their main component was a magnesium-based lime.[18] As in the case of pink-red *cocciopesto* mortars, the presence of newly-formed silico-aluminates, produced by a reaction between the *cocciopesto* and the carbonate bonds, is attested.

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[17] Fieni *et al.* (1998).

[18] Bertolini, Di Leone and Fieni (2004) 225–35.

These ingredients gave the mortar a more or less hydraulic character, depending on their ratio.

Our most significant technological discovery was the presence of gypsum within the mortars: this material is present in such quantities as to exclude the possibility that it was formed as a result of the transformation of carbonate into sulphate as a result of atmospheric pollution. Some of the main qualities of gypsum—such as its capacity to expand and the high speed with which it hardens—were certainly perquisites of thick mortar joints. These factors would also explain how strong walls could be erected without any kind of vertical mould. Large quantities of sand and gravel also contributed to the thickness of the joints.

Variations in the composition of the cement employed in the building have not been surveyed, although, based on the available evidence, it may be stated with certainty that its nature and use did not fundamentally change from the foundation of the building to the Lombard era. The comparison between the manufacture of brick and lime, both heavily reliant upon the existence of kilns and the availability of wood for use as fuel, suggests that the decline in the production of bricks was caused by economic, rather than technological factors. If there had been any decline in technical expertise it would be evident from a technological analysis of the two kinds of production. Even the technique used to put together the external masonry of the complex still survived during the Lombard era. The horizontal and vertical mortar joints were still smooth, totally compact and present some traces of pointing-up (a common feature in ancient brick-masonry, realised by tracing a horizontal line with a sharpened tool on the surface of the mortar between two lines of bricks). Meanwhile, the pointing-up present in certain places of the Saint Aquiline and Saint Sixtus towers, was mainly composed of a thick, lime-based mortar that even covered sections of the bricks. In Saint Aquiline, some pointing-up was present within a very grainy, *cocciopesto* mortar. It is unclear as to whether or not this pointing belongs to the first building phase, considering that thick, lime-based mortar was already present in the oldest section of the Laurentian complex. Whatever the case, the pointing was designed to preserve the mortar joints from the infiltration of water, and maintain the smoothness of the masonry.

Where the plaster covering the brickwork is concerned, our work has not found much that has not been covered by previous surveys of the site. It has often been argued that sections of the plasterwork of San Lorenzo originated in the Roman era. This layer of plaster is still partially *in situ*, on the north and south-west towers. Only one of these sections can be dated; to the first building phase of the complex. The plaster is extremely thick, comprising two layers of 1–2 cm, of which the inner layer (*rinzaffo*) is made of *cocciopesto*, and the outer layer, lime with fragments of sand and gravel.[19]

From a technological point of view, the stratigraphic survey and archaeometric dating of the complex have resolved some important issues. They have suggested that the late antique building work was principally characterised by the use of large, although rarely whole bricks, which had normally been recycled. These were roughly but fairly accurately hewn, and then laid on thick mortar joints with their top ends facing away from one another. The archaeometric dating of these procedures demonstrates that they were still being carried out long into the Lombard period.

Nonetheless, with the passing of time, certain changes concerning the availability of building materials, such as brick, and the professional attitudes of the workmen can be noticed. The quality of the mortar examined by our research, at least on a macroscopic level, and in particular its use in larger quantities, are trends reminiscent of other late antique Milanese buildings, even though their finished masonry work might have been different. Examples include the *opus spicatum* of San Nazaro, or San Simpliciano. Even when bricks were laid in different ways in the other late antique Milanese buildings, the same fundamental building techniques and architectural solutions discussed thus far were present. Bricks were used in a very well-defined and carefully focused manner, apparent from the large amount of lime used in brickwork dating from this period. This phenomenon can be associated with the demolition of buildings, and maybe with soil management practices, both within the urban area.

Judging by the quality of its *spolia*, its capitals, columns, and bricks, the Laurentian building complex was without doubt privileged and rich. These architectural elements all compare favourably to those employed in the Ambrosian complex. Previous studies have already identified within its remains convincing proof that its foundation resulted from imperial patronage. Therefore, future research might now build on a combination of this work and our investigation into the late antique building techniques deployed in the construction of the building, to focus on the relationship between the likely patron, or patrons, and the skill of the builders, masons, stonecutters and plasterers they employed. Indeed, it is undoubtedly the case that a close relationship existed between the level of economic backing and the ability and resources of the craftsmen.

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[19] Roman plaster was studied during the most recent restorations of the north-east and south-west towers: Cecchi (1988).

Vaults and Domes

The vaulted domes of the chapels of Saint Hippolytus and Saint Aquiline are typical of the late antique period. However, whilst the former has undergone considerable reconstruction as a result of structural problems, the latter is perfectly conserved, with the exception of certain changes brought to light by our research. The original chapel roof at Saint Hippolytus was replete with four orthogonal, barrel vaults, on which the central vault, probably supporting the dome itself, had to be placed. This design was to have an extremely important influence on the architectural history of the complex. The 20th c. restoration included the reconstruction of the central dome and the oriental barrel vault, which had previously been renovated by Martino Bassi at the end of the 16th c.[20] The barrel vault was now constructed from concrete. In contrast, the remaining three barrel vaults, which originated in Late Antiquity, were built against the rounded arches upon which the dome was placed. They were made from provincial *sesquipedal* bricks set on their edges, held together by *cocciopesto* mortar. The building technique used for the section between the four barrel vaults remains unclear. Like other monuments of the Roman Age, it probably consisted of a dome on pendentives.[21] Giani discovered the remains of pots—recently identified as African Red Slip—on the exterior face of the vaults.[22]

Meanwhile, the vault in Saint Aquiline was characterised by two different surfaces. The lower face is a pavilion shape, whilst the upper is hemispherical. A gap in the layer of lime-based mortar covering the extrados (the external surface of a dome) allows us to view the texture of the wall. The tops of very thick (7–8 cm.) provincial *sequipedal* bricks are visible. These were bonded with a *cocciopesto* mortar that was much more friable and less rich than those described above. The bricks were placed in a radial arrangement, according to a laying technique that prefaced the centring method. A well-known drawing of the 17th c., attributed to F. M. Richino, represents the profile of the ancient roof. According to this, the roof clearly incorporated a thick level of "*urni ovvero olle*", that is a layer made by amphoras, a typical late antique device to steady a vault. Archaeological and archaeometric surveys have recently demonstrated that Richino's description in fact portrays the late antique remnants of the building, showing either the surviving remains of the first building phase of the chapel (phase I), or phase IV, during which the restoration of the gallery took place.[23]

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[20] Scotti (2004) 179.

[21] For square vaults and *pendentives* or *squinch* see Lugli (1957) 687–88.

[22] Giani (1934) 105; Bocchio (1990) 140.

Recent studies[24] have suggested that clay pipes may have been used as centring during the building of the dome, pointing to an open section of the plasterwork in which a sort of rib in the south side is clearly visible. Chierici, on the contrary, highlighted the poor overall quality of the structure, and ascribed its geometrical irregularities to the displacement of the wooden centring during the hardening of mortar.[25] The clay pipe rib of the vault (fig. 9) has been interpreted as evidence of an operation to correct the geometry of the vault, which had been disturbed during the laying of the bricks.[26] Indeed, the archaeometric survey has confirmed that this development took place at the same time as the insertion of underlying walls. Conversely, the hypothesis that the structure was spoilt by numerous fictile tubes seems, at this point, difficult to sustain. First, Chierici made clear that only a limited portion of the surface was affected and, second, the thermoluminescence dating of the tubes gathered during excavation work—associated, as it will be shown, with the covering of the tetragonal structure—established that they belonged to periods much later than the initial construction phase. Therefore, they may well represent a measure taken on numerous occasions subsequent to the establishment of the chapel, to repair widespread damage to the structure. The latter is indicated by the extent of cracking still visible, particularly in the eastern walls of the chapel.

According to the archaeometric evidence, the gallery's exterior, which was replete with arches and small barrel vaults frequently described in the literature, was more recent, probably dating to the Byzantine

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[23] Fieni (2004c) 161–63.

[24] Cecchi (1985) 96.

[25] Chierici (1951) 131–33.

[26] Chierici (1951) 131–33.

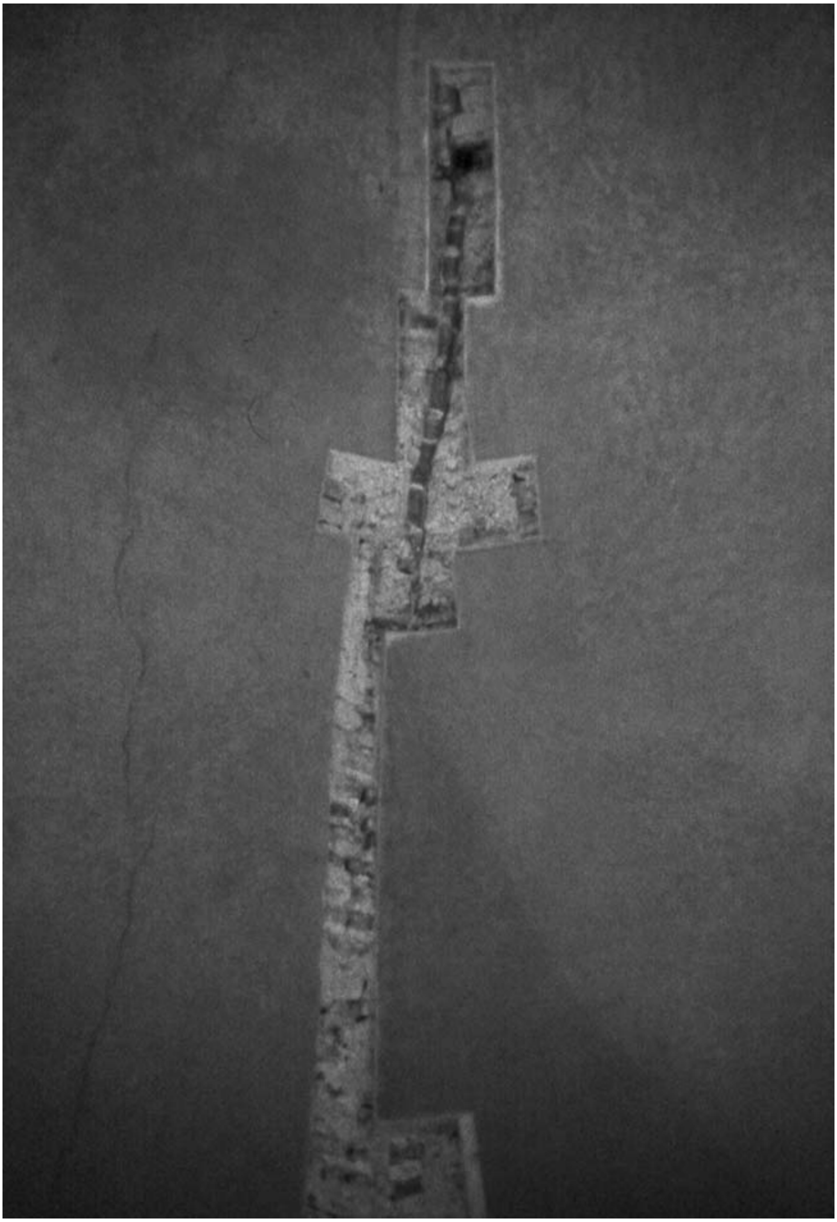

Fig. 9 The clay pipe rib of the vault in the Chapel of St Aquiline.

period (phase IV). As a result, it is harder to envisage how the ceiling was originally connected to the octagonal structure. This question would be even harder to answer if the impression given by the modern iconography of ancient Milanese octagonal buildings is accurate. This suggests that the domes would have been either visible, or hidden by a pitched roof.

Stratigraphic and later, archaeometric studies of the vault originally covering the tetragonal structure have revealed new elements in its construction. Established literature on the architectural history of the building has put forward two hypotheses regarding the original condition of the vault: the first, by J. Kohte, inspired by Byzantine models (fig. 10); and the second, proposed by Verzone and Chierici, by Roman architectural trends (fig. 11). According to the former, the dome was placed on spherical pendentives and had windows inserted at the level of its arches, as did Justinianic churches. Conversely, the latter theory suggests the use of a pavilion covering, as was the case in the chapel of Saint Aquiline. In putting forward this theory, Chierici argued that the use of pendants, as suggested by Kohte, was not a well-developed architectonic solution at the time of the building's construction. In addition to these theories, Chierici has recently proposed another solution to the problem. Having found pieces of tubing during his excavations, he argued that fictile tubes were possibly used in the structure.

However, stratigraphic surveys have revealed that some of the four sets of two pillars which originally supported the vaulted dome erected in Late Antiquity were nearly fully reconstructed in the Medieval period. This work has also made clear that the Medieval replacements survive essentially intact, to the height of the gallery on the eastern side of the church. This research has demonstrated that the oldest pieces of fictile piping can be associated with the medieval reconstruction, and not with the late antique phase. In contrast, archaeological and archaeometric evidence lends weight to the Verzone-Chierici hypothesis that the vault was constructed in *opus caementicium*. It also suggests that the large *Pantheon*, depicted in the Milanese literary tradition, in fact collapsed in the Medieval period and not in the year A.D. 1573, as was recently argued.[27]

The dihedral pillars enclosed a square area of approximately 90 square Roman feet. The wide pillar section, the thickness of the interior

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[27] Kleinbauer (1967) 3; Cecchi (1985) 98.

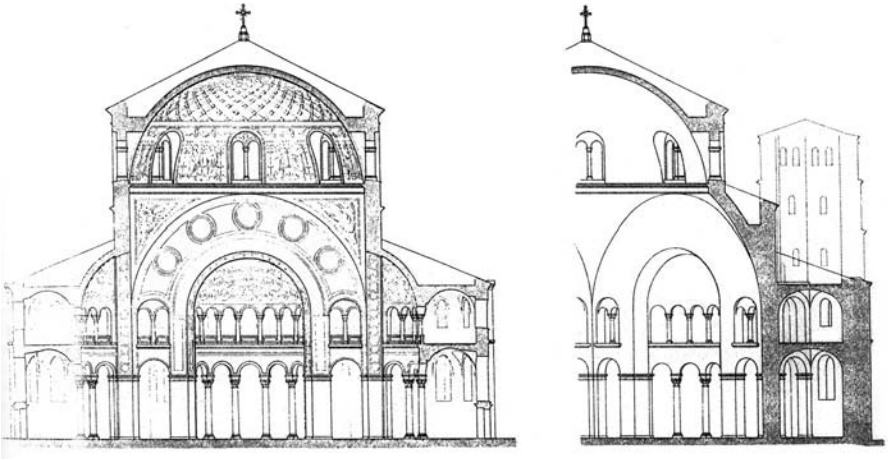

Fig. 10 Reconstruction of the vault: J. Kohte, inspired by Byzantine models.

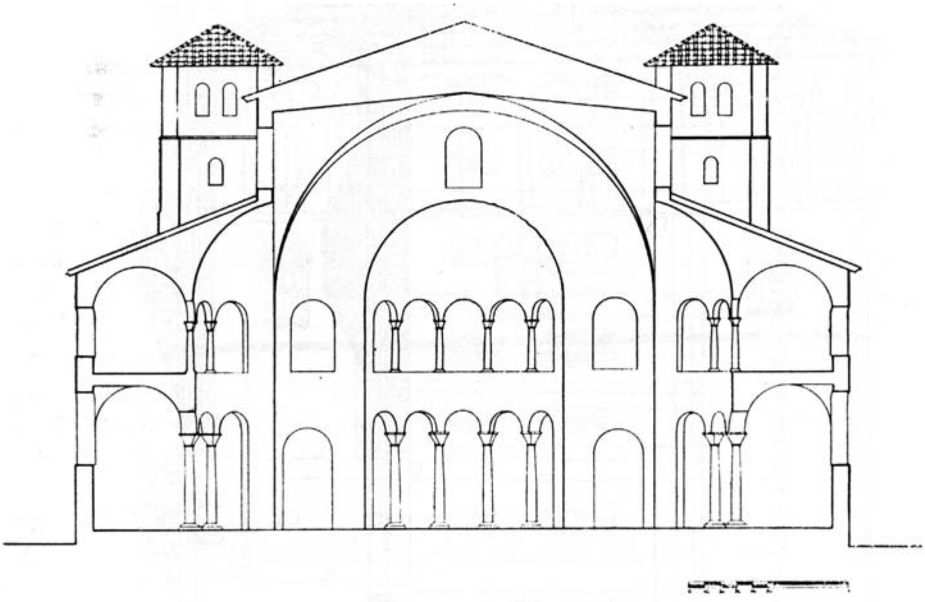

Fig. 11 Reconstruction of the vault: Verzone and Chierici, inspired by Roman architectural trends.

edges of the towers—suggesting a vault impost (as in the north-east tower)—and the ribs that make the walls of four exedras thicken, all suggest the presence of a heavy and outward-thrusting vault.

In spite of these interesting findings, the only firm conclusion we can draw is that the masonry technique was employed in a vaulted structure. The original shape of the vault cannot be precisely reconstructed on the basis of the archaeological evidence.[28] This is because modern reconstruction work has profoundly altered the appearance of the dome and the conches. The latter, now hidden by the angles of the roof, must have originally been visible, while only the gallery would have been covered by wooden beams in Late Antiquity.[29] Meanwhile, the mantle covering the dome and the conches had perhaps been made out of *tegulae* and *imbrices*, or maybe even metal, which would reinforce the Milanese literary tradition, in which San Lorenzo is viewed as the Milanese *Pantheon*. The substantial *opus caementicium* masonry work was in fact able to directly support the covering mantle, as frequently seen in the Roman architectural tradition. Examples include: the Liciniani Horti; the Piazza d'Oro temple; or the Nymphaeum, near to the Pecile in Hadrian's Villa at Tivoli. In the latter case, it is assumed that no underlying, linear structure existed, and that metal or ceramic materials were used in the covering.

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[28] Fieni (2004b) 71–89.

[29] Whilst the archways of the passages between the Roman towers and the gallery still exist—along with traces of the middle age vaults imposts covering the medieval gallery—no trace has been found of the Roman vaulted structures of the tower walls, even when these are well conserved to the same height as the medieval and modern structures. This would suggest that vaulted ceilings corresponding with the gallery did not exist in Late Antiquity.

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PUBLIC AND PRIVATE BUILDING ACTIVITY IN LATE ANTIQUE ROME

Riccardo Santangeli Valenzani

Abstract

This article charts the transformation of the organisation of building work at Rome during Late Antiquity and the social changes that underlay it. In Late Antiquity, the reduction and total cessation of brick manufacture, and the use instead of recycled materials, made it much harder to maintain the standardised, large-scale building methods of the Early Roman period. The scarcity of good-quality materials led to a growing discrepancy between monumental public works, sponsored by imperial and ecclesiastical authorities, and private and residential architecture. Such a development was not merely a sign of 'decadence' or 'decline', but resulted from the emergence of a society rigidly divided between a ruling class that controlled the means of production and an oppressed inferior class, responsible for production activity.

The analysis of ancient building techniques has a long tradition of study in Roman archaeology. However, since the pioneering works of Van Deman and, particularly, of Lugli and Heres (the latter for Late Antiquity), works have focused almost exclusively on the outer appearance of wall facings, classifying these according to the arrangement of bricks and stones, and the thickness and surface finish of mortar layers. These details have generally been considered crucial to determining the chronology of structures.[1] Such studies have inspired similar analyses of buildings dating to the Early and Late Middle Ages.[2] However, more recent works have argued that such external dating criteria are scarcely reliable, especially when considered apart from analyses of the structural function of the walls, their location within the buildings under investigation, and these buildings' type and function.[3] A book recently edited by Margherita Cecchelli represents the culmination of this kind

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[1] Van Deman (1912); Lugli (1957); Heres (1982).

[2] Avagnina *et al.* (1976–1977); Bertelli *et al.* (1976–1977).

[3] Giuliani (2002).

L. Lavan, E. Zanini, and A. Sarantis (edd.) *Technology in Transition A.D. 300–650*
(Late Antique Archaeology 4 – 2006) (Leiden 2007), pp. 435–449

of research for Late Antiquity. It offers a complete catalogue of 5th to 7th c. wall facings in Rome, stressing both their broad variety and the impossibility of using them for anything but very general dating.[4]

Partly relying on my earlier works,[5] in this article I will consider late antique and Early Medieval building techniques as evidence of changes in the organisation of building work and, consequently, in the entire social structure. In an important study some years ago, Mario Torelli associated the introduction of *opus reticulatum*—i.e. the particular building technique of the Late Republic that accompanied the climax of slave-based production—with a major change in the organisation of building work, which was now based on a highly specialised labour force and a rigid subdivision and standardisation of working procedures.[6] The use of a modular element—the small prismatic tuff stone—produced in large quantities, in a standardised form and size, and used by a specialised workforce, made it possible to optimise the hours worked on a building site. This had not previously been possible with the *opus incertum* technique. This was a major improvement, as previously a master mason using the *opus incertum* technique had to choose and cut to the correct size each individual stone to comprise the outer wall facing. However, according to Vitruvius, the penalty paid for this quicker construction technique was lower quality and less durable structures: continuous oblique joints made masonry work more vulnerable to fractures, a phenomenon that is confirmed by innumerable examples in the archaeological record.[7]

If I may draw a modern parallel, there is a strong analogy between the transformation just described and the early 20th c. transition from traditional, local craft production, to assembly line manufacture on a large-scale. In spite of obvious and fundamental differences between the organisation of ancient slave labour and modern liberal-capitalist labour, it is clear that, in both cases, working-hours were optimised and profits maximised through a division of labour. Meanwhile, both of these developments meant that craftsmen lost complete control over their work and over its final result, leading to the deterioration of overall standards.

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[4] Cecchelli (2001).

[5] Santangeli Valenzani (2002).

[6] Torelli (1980).

[7] Vitruvius, *De Arch.* II, 18, 1.

A famous passage in Plutarch's *Life of Crassus* shows the kind of organisation that lay behind this transformation of building methods in the Late Republican period and the social level at which it was managed. It describes the manner in which the later triumvir had become rich by property speculation: "he begun by buying slaves who were architects and masons. When he had more than 500 of them, he started to purchase houses that had been destroyed by fire and the adjacent ones, which their owners sold at a low price because they feared that the buildings would collapse. In this way he acquired the majority of Rome".[8]

Throughout the Principate, building techniques centred on the use of *opus caementicium*, with wall facings in pre-prepared modular elements—such as the *opus reticulatum, opus mixtum* and *opus latericium.* These demonstrate the continuing organisation of work based on specialised enterprises, such as that owned by Crassus. However, literary and epigraphic sources suggest that the upper class was no longer involved in the building trade, which was now the preserve of economically prosperous men of a more modest social rank. Such is the case of Quintus Haterius Tychicus, who drew up a series of lucrative contracts in an extraordinary period of building activity under the Emperor Domitian; his famous funerary monument not only shows his considerable economic resources, but also his adherence to the figurative, symbolic and ideological culture of the popular class. This is not to say that the ruling classes had ceased to participate in profitable activities associated with the building trade. Rather than organising building work, they now produced building materials, as the owners of brickyards. Because brickyards were habitually located within substantial landed estates, this activity was deemed a venture more appropriate to the *dignitas* of a senator than the enterprise of Crassus, so clearly disapproved of by Plutarch.

A number of brick stamps dating to the first centuries of the Imperial period bear the names of the highest-ranking Roman aristocrats. Many studies, most recently those on the Forum of Trajan, have proved that noblemen, including members of the imperial family, supplied the building materials used in monumental public buildings.[9] It seems likely that the sources from which other building materials derived, such as the limekilns and quarries of tuff stone and *pozzolana*, were also in the hands of senatorial and equestrian aristocrats, although there is no evidence so accurate as the brick stamps to prove this.

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[8] Plutarch, *Life of Crassus*.

[9] Bianchi and Morbidelli (2004).

However, the centralised nature of Roman building work and the high level of specialisation in production processes does not lessen the importance of large numbers of unskilled labourers. These men were vital to those activities which did not require particular skills, such as the transportation of earth and building materials. In a digression on a passage in Suetonius' *Life of Vespasian*,[10] Brunt emphasised that this unspecialised workforce was not made up of a mass of slaves, as was thought for a long time, but rather of the free inhabitants of Rome, the *plebs urbana*. The daily wages which were guaranteed by large public building projects were one of the principal sources of income for the urban plebs. According to a well-known anecdote, Vespasian rewarded the designer of a machine that made it possible to transport giant columns destined for the Temple of Jupiter, but then refused to use it, declaring that he wanted to 'continue to feed the people'.[11] It is clear that, by involving an enormous number of unskilled labourers, the monumental public building projects promoted by the emperors served in part to redistribute resources, and exercise social control. Recently, Roberto Meneghini calculated that the levelling of the slope of the Quirinal, which was necessary for the construction of the Forum of Trajan, required the removal and transportation over a long distance of 316,000 m^3 of earth and debris, which would have taken 1,000 workmen a whole year.[12] The redistribution of resources through public building projects was certainly not unique to the Roman world, but was characteristic of all pre-industrial urban centres, especially those which were seats of political power.

This very broad base of unskilled workers, always needed to carry out unspecialised manual tasks, did not impinge upon the heavy specialisation of the building sites. This specialisation was necessary to ensure the speedy completion of targets, and the uniformity and standardisation of the work. Regarding speed, an idea of the time usually taken to erect the walls of Roman buildings has been given by Rita Volpe's timely publication of 28 inscriptions discovered in one of the cryptoporticoes of the Baths of Trajan on the Oppian Hill.[13] Various dates, that are depicted in red paint on the wall facings were clearly intended as an accounting system to monitor the progress of construction work. The walls of the cryptoportico, which are 38 m long and more than 14 m high, were built in less than two months, thereby indicating a much higher speed of execution than was generally thought to have been possible. It is also worth mentioning that the succession of dates displayed on the walls shows that workers had no fixed days off, and even continued to work during the most important religious celebrations of the Roman calendar, such as the *Palilia*, a celebration which took place 11 days before the *calendae* of May, or 21st April.

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[10] Brunt (1980).

[11] Suetonius, *Vita Vespasiani* 18.

[12] Bianchi and Meneghini (2002).

In terms of the uniformity and standardisation, archaeological evidence offers unequivocal proof that, in Early and Late Imperial Rome, there were no recognisable differences between buildings that were constructed with public, imperial or aristocratic funds, and ordinary houses, generally consisting of multi-storeyed buildings or apartments that are usually, but in fact erroneously, defined by archaeologists as *insulae*; the same observation applies to the funerary constructions of the middle or lower classes. Obviously, there were enormous differences in the dimensions and architectural characteristics of the structures, and the wealth of their decorations and wall coverings, but there were no fundamental technical differences between brick or *opus mixtum* walls in Hadrian's Villa and the Imperial Fora, or the contemporary walls of an *insula* in Rome, or Ostia. The type and accuracy of the wall facings, the quality of the *pozzolana* mortar, and the composition of the concrete core of their walls were identical, as were the type and solidity of their wooden scaffolding, which can be deduced from the dimensions and pattern of the holes in the masonry that had been used to support scaffolding. Further, sophisticated technological solutions, such as the relieving arch, were widely employed. This was inserted into walls to concentrate their weight at certain points. The uniformity of such characteristics stemmed from the monopolisation of the building industry by a relatively small number of entrepreneurs (*redemptores*), who were freemen or freedmen. These men were the owners of companies founded on slave labour, which were also part of larger corporations, such as the *Fabri Tignuarii* in Ostia. The corporations, probably like the better-known medieval ones, established quality standards, and took part in both large-scale, public, and private, residential building projects.

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[13] Volpe (2002).

The situation began to change from the 4th c. Our discussion of the Early Roman period has provided a context within which it is possible to understand the changes that occurred in Late Roman building work, and their relationship to wider social changes. The organisation of work in small to medium-sized specialised companies is still testified in the 4th c. According to the most recent analyses, the funerary hypogeum of Trebius Justus on the Via Latina can be dated to around the middle of that century.[14] Like Haterius, mentioned above, he owned a building company, and did not have a very high social status, despite being extremely wealthy. Such cases were common in 4th c. Roman society, in which non-aristocratic classes tended to be denigrated. To Trebius Justus we owe the most complete illustration from the ancient world of the work of a building company. The walls of his tomb depict and list the names of his employees. They were obviously all slaves, judging by their single names, starting from the master-builder, *magister Generosus*, who is portrayed holding a trowel and a measuring-rod. Even a mule, *Leporius*, merited a place on this ancient equivalent of a group photo, bearing a pack-saddle loaded with bricks, and guided by a young man named *Fortunatus*. On another wall of the *hypogeum*, the group is working on the construction of a building: masters are laying bricks from positions on the scaffolding; one person is mixing lime in front of the wall; and labourers are providing their colleagues with mortar and bricks (fig. 1). On the principal wall of the *hypogeum*, Trebius Justus is depicted supervising the agricultural harvest and, accompanied by his family, displaying money and precious objects on an embroidered cloth. These were perhaps funerary offerings to his young son, Trebius Justus Asellus. Trebius' clear intention was to advertise his wealth and social status within an ideological language familiar to the ruling Roman classes, by representing himself as a landowner. This proud and detailed illustration of the financial success and social status of a Late Roman building, contractor is the closest thing to the work ethic of the capitalist bourgeoisie, as defined by Weber, that the Roman culture has transmitted.

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[14] Rea (2004).

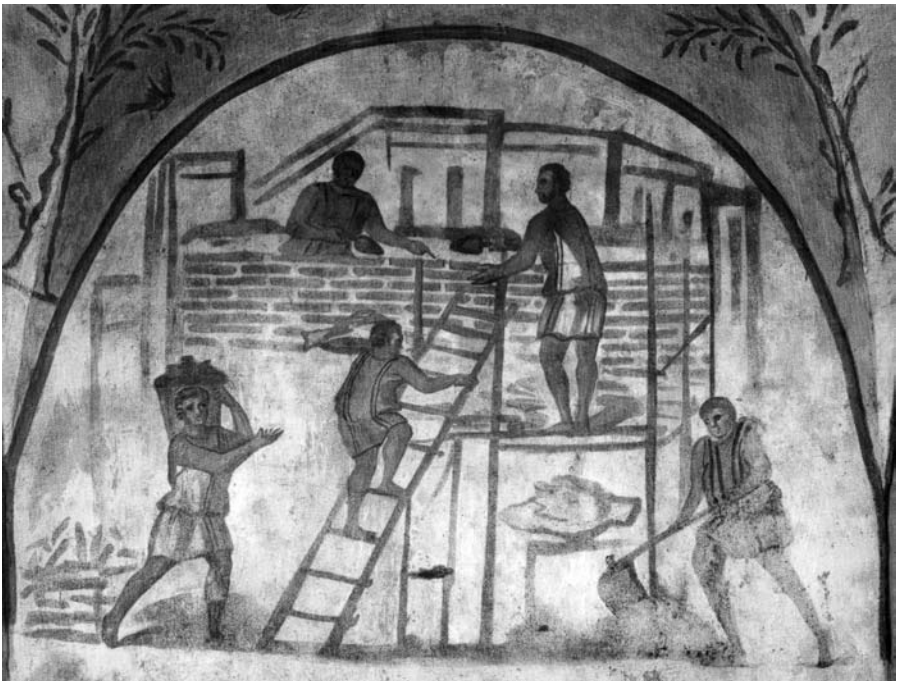

Fig. 1 Hypogeum of Trebius Justus, Via Latina, 4th c., showing a group working on the construction of a building.

However, while Trebius Justus was having his *hypogeum* decorated, the society in which he lived was changing rapidly and heading towards a very different future. One of the most obvious changes in the organisation of building work at Rome during Late Antiquity was the reduction and, later, total cessation of brick production. The kilns still in use by the middle of the 4th c. produced only roof tiles. This production was, nonetheless, somewhat limited in volume and, at least in the case of the private *domini* brick stamps, probably not aimed at the commercial market, but connected with specific building projects, or intended for the maintenance of property belonging to senatorial families. At least from the second half of the 4th c., the majority of building materials were recycled. This was not only the case with marble revetments and decorative architectural elements, which are the most researched aspects of the phenomenon, but even with brick and tuff components. Further, the *pozzolana* quarries, producing the volcanic earth responsible for the extraordinary quality of the Roman *opus caementicium*, curtailed their production. Some recent studies have demonstrated that the *pozzolana* in the mortar work of some late antique buildings was partly substituted with crumbled tuff stone.[15] Meanwhile, in Portus, late antique mortar is easy to recognise because it is mixed with sand, at least from the 6th c.[16]

Some legislative decrees of the 4th and 5th centuries regulated and, in fact, approved of the spoliation of abandoned or dilapidated buildings. Nevertheless, they do not give us any clues concerning the most historically important element of this process from our point of view: the identity of those responsible for dismantling and the sale of recycled materials. A few inscriptions show that the dismantling and recycling of materials from famous public monuments was organised by high-ranking aristocrats such as *Patricius Decius*, whose name appears on a column that was once part of the Temple of Mars Ultor at the Forum of Augustus.[17] Another was *Gerontius vir spectabilis*, in all probability the senator of the same name living in the Gothic period, who was involved in dismantling a sector of the Colosseum.[18] Although we cannot generalise regarding the significance of this trend, there are further examples of the major efforts that sometimes went into this recycling activity. The removal of brick wall facings from the Antonine Baths and Hadrian's Villa must have required the use of sizeable scaffolding structures and the participation of vast labour forces. These cases indicate that such operations cannot be considered merely as sporadic activities that happened without any regulation, as was widely assumed to have been the case until a few years ago, when Late Antiquity was mainly regarded as a period of decline. Instead, the examples mentioned above show us that the spoliation and re-use of building materials were carefully planned projects involving the upper classes.

Nonetheless, the fact that *spolia* were the only building materials available must have had a visible effect on the building industry. We have seen how the use of standardised building materials lay behind the speed and regularity of building work in the Early Roman period. It was hard to maintain this highly efficient system using re-used pieces of brick and stone that varied considerably in size and shape. For instance, it was extremely difficult to arrange brick of different thicknesses in regular and smooth horizontal layers. As it was also necessary to employ bricks which had lost their triangular shape, the bonding between wall facings and their cores tended to be looser in Late Roman buildings, resulting in their overall structures being overall much weaker than their Early Roman predecessors.

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[15] Saturno (2002).

[16] Coccia (1993) 193.

[17] Meneghini and Santangeli Valenzani (1996) and (2004).

[18] Rea *et al.* (2002); Meneghini and Santangeli Valenzani (2004).

Besides the use of much shoddier materials in comparison to the earlier period, other developments point to the decreasing quality of the work carried out at Late Roman building sites. Fewer 'discharging arches' were inserted into the walls, and when they were, they were often badly centred. There were fewer and more irregularly-placed holes for the scaffolding. These characteristics all point to much simpler construction techniques. In spite of these limitations, prestigious buildings, such as churches, continued to possess walls of a very high standard until the 7th c. This is proof that aristocratic and imperial and, later, papal commissions, continued to erect or restore public buildings to a very high standard. In this way, they ensured the survival of centres of specialised craftsmanship, which maintained centuries-old working traditions (fig. 2).

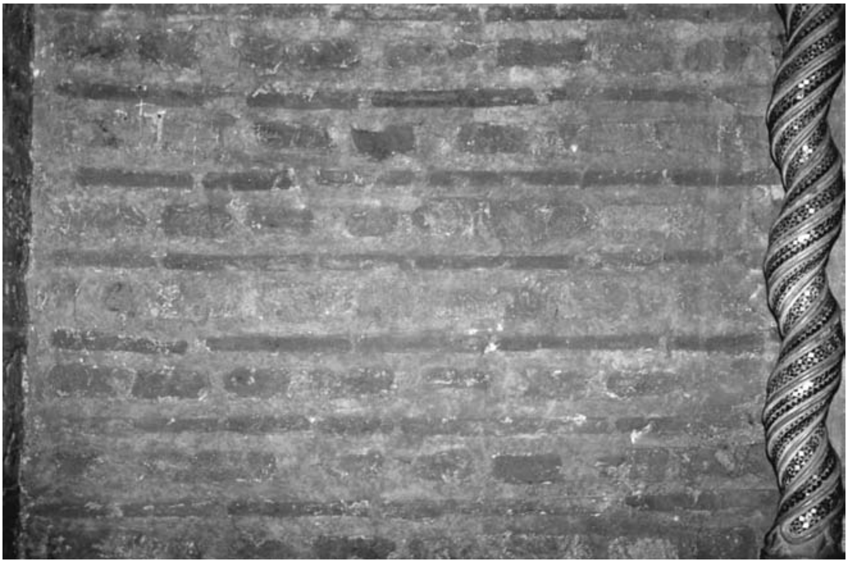

Fig. 2 High standard of wall facing
used in monumental buildings until 7th c.

The growing discrepancy between the quality of, on the one hand, public, prestigious buildings and, on the other, private and residential structures, is another important characteristic of late antique architecture. There is far less evidence of the latter because, until a few years ago, the remains of middle and lower class residential housing tended to be demolished indiscriminately and merely recorded as 'rough walls of a late date'. The surviving remains are, however, sufficient to demonstrate that domestic architecture was no longer standardised as it had been in the Early Roman period. The surviving masonry work from late antique residential structures shows that tuff stone was used more predominantly than re-used bricks, even in those belonging to the upper, if not most prestigious, classes. The re-used bricks were used randomly, with no previous selection, as too were small slivers. Heterogeneous stone blocks, paving-stones and fragments of *cocciopesto* were also incorporated. Oblique brick layers, and sagging, lop-sided and badly aligned walls serve as examples of the kind of shoddy workmanship that might fit quite comfortably into a 'how not to' guide for the unskilled mason (fig. 3).[19]

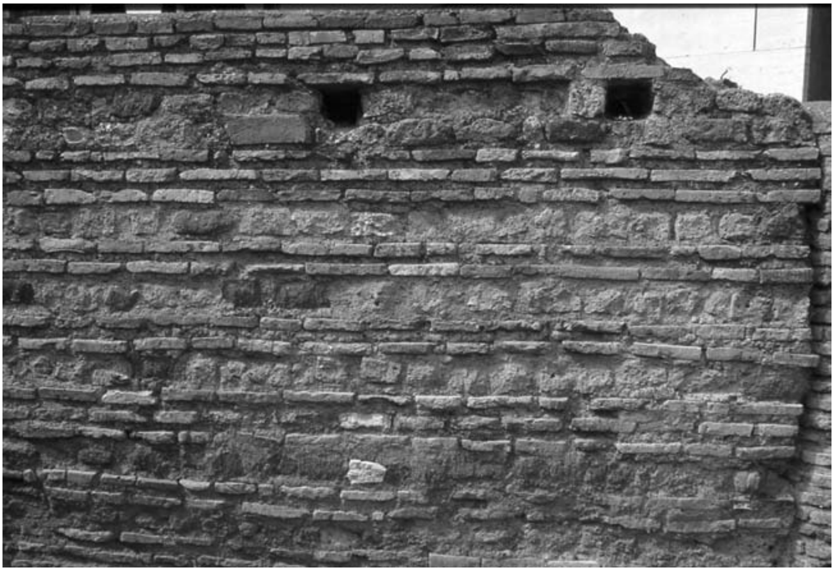

Fig. 3 Masonry typical of late antique residential structures: unselected re-used bricks, heterogeneous stone blocks and other material.

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[19] Heres (1982) 52–53.

Therefore, it is clear that in Late Antiquity, especially from the 5th c., the organisation of building work was typified by two trends. First, highly skilled master builders continued the building traditions of the previous era. Although they suffered from the inevitable difficulties caused by the scarcity of good-quality materials, they maintained a high level of technical skill, and were employed by the upper classes in prestigious building projects. Second, unskilled labourers with little or no experience were also employed. They were usually related to building contractors through patronage networks, and were placed under the supervision of master builders. In another historical context, heading 145 of the Edict of Rothar explicitly depicts such an arrangement, describing the appointment of a *magister commacinus*, who was charged with co-ordinating the work carried out by the dependents of the patron, people who had only a generic competence.

Such trends came to an end in the 8th c. Thereafter, the characteristics displayed by lower quality late antique structures permeated all levels of building activity. In the mid-8th c., a new construction technique was introduced in Rome. This utilised re-used tuff, or *peperino* blocks, that were often roughly cut into small pieces of a more manageable size, and then joined together without mortar, in a kind of poor-quality *opus quadratum*.[20] The earliest dated example of this technique is provided by the apse of the church of S. Angelo in Pescheria, built in the year A.D. 755. From this period, the technique was widely used in the construction of churches, public buildings in general, and aristocratic mansions, to such an extent that archaeologists now consider it to be the best indication that a building dates from the 8th to 9th centuries (fig. 4).

The diffusion of this technique had an extremely important influence on the organisation of building work in this period. This stems from the fact that it made possible the construction of buildings without the involvement of large numbers of specialised craftsmen, and principally required manual labourers to move and lift large blocks sometimes weighing several quintals. However, at the same time, it made the resultant buildings vulnerable to structural weakness and meant that they could not be erected to a height of more than 3 to 4 m. On the upper floors, a kind of *opus latericium* was used, although not with the regularity and accuracy apparent from the ruins of prestigious buildings

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[20] Santangeli Valenzani (2002); Meneghini and Santangeli Valenzani (2004).

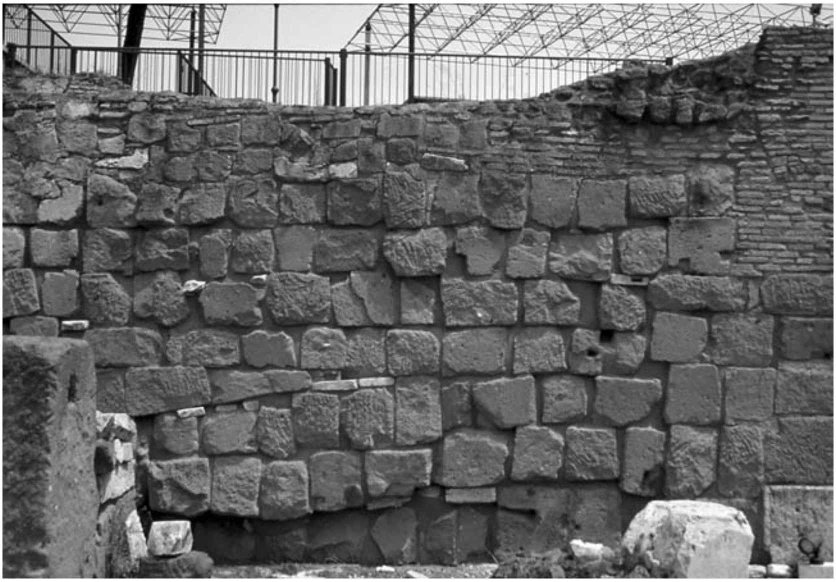

Fig. 4 Building work in re-used tufa blocks, characteristic of the 8th–9th c. in monumental buildings.

in Late Antiquity (fig. 5). Lower level dwellings were now constructed with unmortared walls comprising heterogeneous material (fig. 6), or with raw clay in what looks like a sort of spontaneous building practice, judging by ethnographic comparisons. These buildings were erected by individual families, who sometimes relied upon the help of local community members, thus drawing upon a shared knowledge.

To sum up, it is clear that from the 8th c., as was also apparently the case with other aspects of material culture, highly-skilled, specialised building techniques were close to disappearing; this was the culmination of a trend already apparent during Late Antiquity, i.e. the reduction of specialisation in working processes. I have argued elsewhere that this change can be placed in the context of a simplification of the social structure as a whole, in the region around Rome, within which a polarisation between two classes occurred.[21] While on the one hand, a ruling class had come to control the means of production, on the other hand, the majority of the population belonged to an inferior class that

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[21] Santangeli Valenzani (2002); Santangeli Valenzani (2004); Meneghini and Santangeli Valenzani (2004) 24–27.

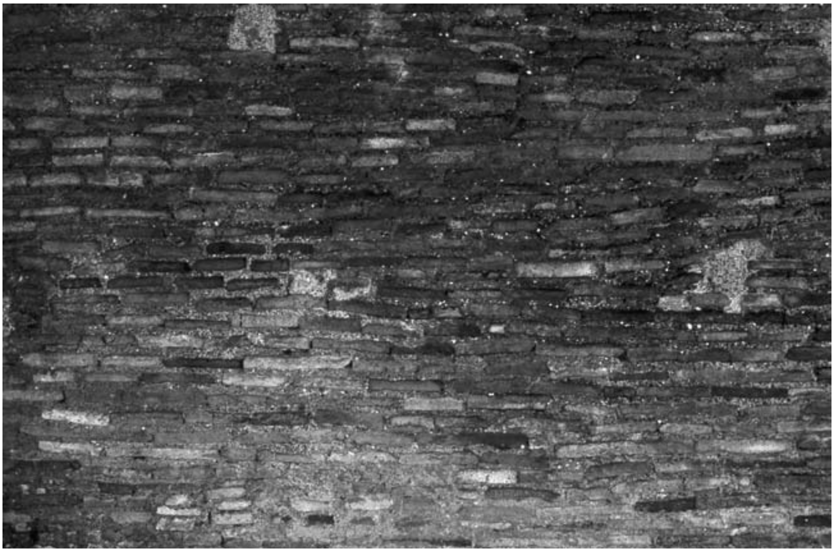

Fig. 5 Type of *opus latericium* used on upper floors in the 8th to 9th c. in monumental buildings.

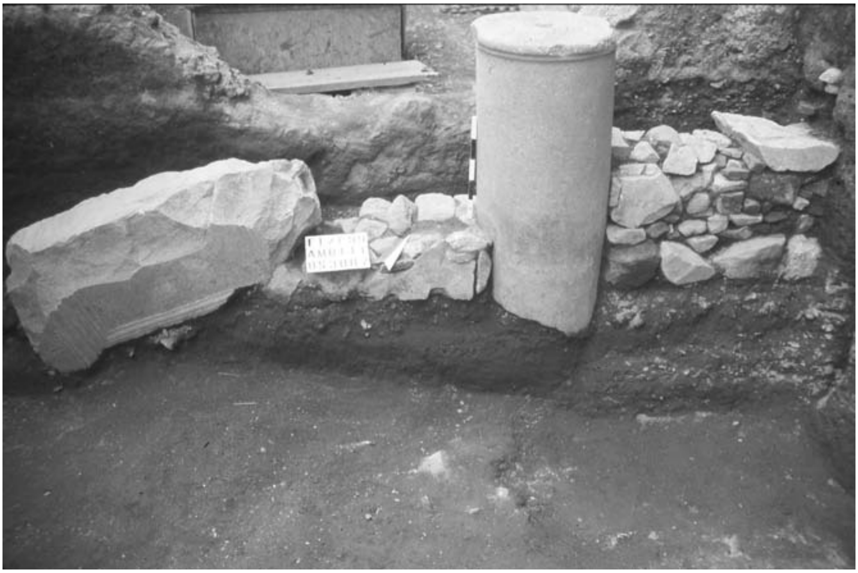

Fig. 6 Unmortared walls of hetrogenous materials used in 8th–9th c. for modest structures.

carried out the majority of production activity, and was connected to the ruling class through networks of patronage. This social structure was perpetuated by the ability and willingness of the ruling elites to suppress the inferior classes, with the use of violence in the case of the warrior aristocracy, and ideology in the case of the ecclesiastical leaders. However, this simplified society still had some room for specialised workers, such as metal-workers, artists, potters, and, as we have seen, the master builders who were involved in elevated, monumental public and private building projects. Still, even in these fields, the tendency is towards a reduction to the essential. Indeed, the construction methods evident in the remains of lower class dwellings clearly point to the autarchic organisation of all types of production, mostly at the level of the family unit.

To conclude, the evolution of building techniques and practices on late antique and Early Medieval building sites should not simply be dismissed with the old fashioned label, 'decadence'. Rather they offer insights into the transformation of social, political and economic structures during the last centuries of the 1st millennium A.D., the turning point in the evolution of European history.[22]

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[22] Meneghini and Santangeli Valenzani (2004).

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ARCHITECTURE AND INFRASTRUCTURE IN THE EARLY MEDIEVAL VILLAGE: THE CASE OF TUSCANY

Marco Valenti

Abstract

This article discusses the design and architectural structures of Early Medieval rural settlements in Tuscany, covering the period between the 7th and 10th c. It considers hut types, granaries and store-buildings, along with enclosures, roads, courtyards and artisanal structures. The construction of palisades, ditches and stone fortifications is also discussed. Technological characteristics are discussed in detail. A social interpretation of village development is presented. The origin of village settlement seems to be in the reaction of rural populations to the failure of centralised leadership in Late Antiquity, through the formation of communities, of an egalitarian nature, to cope with changed circumstances. The increasing structural complexity of the settlement is connected to the emergence of a resident elite.

INTRODUCTION

The nature of settlement and housing between the 6th and 11th c. has long attracted interest, and occupies a central place in studies of the transition from the Roman to the Early Medieval world, and the formation of Europe. It is a topic that has long been studied through texts, both secular and ecclesiastical; but only in the last three decades has the contribution of archaeology been felt and an interdisciplinary approach developed.

In some countries, the study of late antique and medieval settlements has its origin in political and cultural curiosity of a romantic and nationalistic genre. However, with recent quantitative and qualitative developments in archaeological research, new interpretations on the transformation of the late antique world have emerged. Because of an exponential growth in the number of sites known, it has become possible for archaeology to complete and, above all, to question the

L. Lavan, E. Zanini, and A. Sarantis (edd.) *Technology in Transition A.D. 300–650*
(Late Antique Archaeology 4 – 2006) (Leiden 2007), pp. 451–489

schemes drawn up by earlier scholars. Earlier hypotheses did not consider material evidence; their results were undoubtedly less well-founded and further away from the reality of Early Medieval rural life.

The formation of Early Medieval settlements and their structural characteristics (village plans, house types, annexes and workshops, population, economy) has occupied an important place in the archaeology of medieval Europe for almost thirty years. Here, constraints of space make it difficult to provide a full account of the history of research to date, but a very basic outline is offered instead.

The systematic study of Early Medieval settlement has only really taken place in Germany, Sweden, France and England. From amongst the scholarly works that have appeared to date, the following contributions can be regarded as key works: the synthesis of Chapelot and Fossier in 1980; the more or less contemporary work of Donat; the critical remarks of Zadora-Rio, supported by the works of Lorren and Périn;[1] and, finally, the recent publications of Hamerow. Each author has presented a diachronic analysis of the characteristics of settlement forms and of the socio-economic relations of occupation centres. The ultimate goal of this research has been to understand the means by which local notables asserted their influence over farmers, through changes in the organisation and management of land. Such an approach logically includes the investigation, analysis and classification of structures that make up settlements. To investigate Early Medieval rural building means therefore to contribute to our knowledge of the end of the Roman landscape and of the birth of post-classical settlement forms.

The Village and the 'Non-Village'

The nature of the Early Medieval village has been discussed from many different points of view, which are sometimes, as in the case of Fossier, influenced by pre-existing models[2] through which one views the material evidence. The schemes suggested by Fossier have produced the most heated discussions of the debate. His basic proposition is that the central economic event of the Middle Ages was the progress stimulated by agricultural expansion after A.D. 1000, by the leading role of the farmer, who transformed himself into a free man and who contributed to the foundation of villages, which are structured in settlement forms that did not exist in the Early Middle Ages. These communities were autonomous and characterised by the collective use of resources, rules, and by clearly marked boundaries between agricultural districts. In contrast, the Early Medieval countryside had a comparatively small population, with rarefied and precarious habitations of modest dimensions. The village did not exist until at least the end of the 10th c.

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[1] Lorren and Perin (1995).

[2] Fossier (1968).

Fossier, in cooperation with Chapelot, used archaeological sources to support this reconstruction.[3] The main problem with these conclusions is that they relied on incomplete data and that information from a few excavations was over-generalised. In Germany, the same misunderstanding also existed, namely that nucleated settlements, which were very irregular and rather diffuse, were the predominant form of occupation. This view was challenged after the 1970s, when a series of systematic and large-scale excavations demonstrated the presence of planned, long-existing villages. They were composed of farmhouses, that had the same orientation, were aligned, and were regularly divided by a planned road network.[4]

At the same time as the volume of Chapelot and Fossier, the work of Donat was published, which still today represents one of the great landmarks in research into Early Medieval settlement structures. Donat is often associated with his effort to produce typologies of settlements and buildings. But despite this, his analysis is in fact principally focussed on the socio-economic relations of the countryside, rather than on construction techniques and their diffusion. It is an example of modern *Siedlungsarchäologie*, that has concentrated on the eastern Frankish kingdom and the settlements of western Slav populations. In this work Donat severely criticises earlier models of Early Medieval settlement, which stress instability and temporality, being characterised by farms or very small nucleated centres (*Kleinsiedlungen* or *Weiler*). He never questions the existence of the village, which was characterised by a population of about 150 persons and whose concentrated appearance was due to the presence of a series of adjacent farm-factories (*Höfe*).[5]

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[3] Chapelot and Fossier (1980); see also Fossier (1984) and (1990).

[4] Donat (1980) 134.

[5] Donat (1980) 133–36.

The same point of view is expressed in Hamerow's publication on Early Medieval settlement in north-western Europe, which bears the significant subtitle: *The Archaeology of Rural Communities*. The model of Fossier's 'non-village' has been totally rejected, though it had been more or less unanimously accepted by historians, who were very often distracted by the indications of documentary sources.[6] In reality, the archaeological data demonstrate that the economy, and cultural interaction between occupation centres, was very complex, with a slow demographic increase in the 7th c. and a bigger expansion of populated areas. This tendency was accompanied by a reorganisation and consolidation of settlements, in the 8th c. especially. New administrative structures were established in rural communities of higher rank—'central places'—which had a market, political control over a territory and an almost exclusive presence of artisanal activities. The founding of such settlements often involved the dismantling of the ancient tribal organisation. Like Donat, Hamerow interprets the village as a complex of farms. It was a big community, or a part of it, and there existed 'structures' used by the entire population, which reveal a commitment to community and shared choices, which were aimed at better land management.[7]

Zadora-Rio is the most prominent researcher to have questioned the character of Early Medieval settlement in France. Her works initially favoured the model of Fossier. In 1990 she proposed a model of settlements divided into small fractions, with buildings made of perishable materials, that were only occupied for short periods. They were located close to more ancient sites, or reoccupied abandoned structures of villas, which were sometimes used as burial grounds.[8] In 1995 her thoughts had changed and she intervened in the debate that had broken out amongst archaeologists in reaction to her work. She compared two types of village, that of the written sources, and that known from material evidence. The comparison showed no common ground at all; she suggested that archaeological research should mainly focus on the geographical concentration of settlement and on the detailed study of agrarian morphology, whilst she remained convinced that historical texts made certain radical conclusions unavoidable.[9] Now that much of her proposed program has been realised, Zadora-Rio takes a different position. In 2003 she openly emphasises that the textual research has not taken into account models that are derived from archaeology, while the information that is obtained from material sources radically changes most of the history of the Early Middle Ages. Archaeology reveals precisely the kind of village organisation and stable communities whose existence had been firmly denied.[10]

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[6] Hamerow (2002).
[7] Hamerow (2002) 54.
[8] Zadora-Rio (1990).
[9] Zadora-Rio (1995).

In Italy, this debate has come later and only recently has anyone started to discuss the characteristics of Early Medieval settlement. An overall picture of rural occupation, based on archaeology, is now acquiring a certain consistency, though much remains in darkness. Unfortunately, there have been no major regional syntheses written so far, which might be used for comparative purposes, though some preliminary attempts have been made.[11] Whereas the structure of rural habitation between the transition period and the Early Middle Ages is quite well-known for the whole of central northern Italy, cases of intensively investigated settlements, from between the 7th and 10th c., are few. Until now, with the exception of Tuscany, solid data is only really available for the decades following the end of the villas, whilst the settlement forms of subsequent centuries remain obscure.[12]

Moreover, in Italy we have not yet compared the results of archaeological investigation with models derived from documentary sources. The latter have proposed settlement models characterised by small occupation centres and largely scattered houses. Such textual research has never outlined the form and appearance of the village, even going as far as to deny its existence, and has almost always separated the village from the organisation of the rural economy. Material evidence has been used nearly exclusively, in manuals and monographs, to illustrate the Early Medieval farmer's house and to confirm how much wood was used at the time. So far, scholars have always tried to connect the proposals of archaeologists with models based on written sources.[13]

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[10] Zadora-Rio (2003) 5–8.

[11] See especially Francovich and Noyé (1994); Brogiolo (1994); Fronza and Valenti (1996). For Tuscany Francovich, Cucini and Parenti (1990); Valenti (1996) and (2004).

[12] See for example Brogiolo (1996) as well as the recent seminar of Gavi (Brogiolo, Chavarria and Valenti, 2004), where the majority of the Italian studies went no further than the 7th c., though the theme included the period of the 6th to 9th c. See: http://archeologiamedievale.unisi.it/dopoleville/index.htm

[13] See for example Pasquali (2002) and Galetti (1987), (1994), (1997) and (2001).

Research in Tuscany on Early Medieval Settlement

The nature and formation of the Early Medieval settlement has been the subject of much work by the *Area di Archeologia Medievale* of the University of Siena: this has resulted in a view of rural change in this period which has been defined by other research groups as the 'Tuscan model'.

The principal characteristics of the model are as follows:

i) A decline of the villa system and of the organisation of rural occupation between the 5th and 6th c., progressively increasing in intensity.
ii) The formation of the Early Medieval village around the beginning of the 7th c., with a move towards nucleated settlement as the predominant of occupation.
iii) A 'weak' role for aristocracies, at least up to the middle of the 7th c. However, they do take some important initiatives for the organisation of the countryside, especially from the 8th c. onwards.
iv) The transformation of many villages into estates, which is realised by the adaptation of the *curtis* to the structures of the village itself during the 9th c.
v) The development of villages into castles, in which the economic aspects of land management and the impression of territorial domination come together, in the 10th c.

The archaeological record, which underpins this model, rests on a microscopic examination of the regional territory, based on twenty years of survey and excavation. The sites investigated have included: towns and villages composed of huts, which are often found beneath castles; minor settlements, such as cave-dwellings; isolated settlements of the 5th-mid 6th c., and some churches. This work can now be set alongside: the extensive investigation of the archives of castles, which has now considered more than 1500 centres;[14] a systematic examination of the territory through aerial photography and satellite photographs;[15] the analysis of data through large databases and GIS platforms;[16]

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[14] Francovich and Ginatempo (2000).
[15] Francovich and Valenti (2001).
[16] Valenti (1998).

and also the intensive sampling of organic finds from all excavations, which have been radiocarbon dated. Some investigations are still in progress and we know little or nothing about them: however, we can now count 49 excavations of castles (17 conducted by the University of Siena), 3 fortified settlements interpreted as small *castra*, 4 isolated houses of the late antique period, 5 caves frequented in Late Antiquity and at the start of the Early Middle Ages, 18 villas, 12 churches, and 3 open villages with late antique and Early Medieval phases (Callemala, Luscignano, San Genesio). The field surveys in the region take into account all periods as much as possible. Of the provinces of Siena and Grosseto an area of 1979 km^2 (almost 9% of Tuscany) has now been investigated, with a total of 10,110 archaeological sites located, whereas the geo-referenced total derived from a survey of other provinces, now underway, already reaches 5,363.

This is the data on which the so called 'Tuscan model' is based. Such a term usually reflects only a limited number of meanings which might permeate it. For us it only has value in being the product of investigations carried out within a given territory. What has been elaborated is in fact an interpretative model for settlement pattern transformation between Late Antiquity and the Early Middle Ages, that originates from more than twenty years of investigation in Tuscany; such a comprehensive research strategy, backed up by a very significant archaeological data sample in numerical terms, presents itself as a point of comparison in the Italian debate.

Work in Tuscany reveals that rural survey, alongside the excavation of villas, nucleated settlements, (e.g. *mansiones* or *vici*) and sometimes churches, mainly informs us about the end of the Late Roman countryside and the transition to the Early Middle Ages. This is also true in central northern Italy, where work has especially focussed on the end of the Roman villas and the effects of change up to the 7th c. In contrast, the study of *incastellamento* seems to be the most profitable strategy to understand the characteristics and chronology of Early Medieval occupation. The modern excavation of entire hills, in which thousands of cubic metres of soil have been carefully removed, has delivered the most significant results.

The Structures of the Early Medieval Village in Tuscany

The most obvious aspect of the formation of the Early Medieval village is the total predominance of perishable building materials, along with the rare use of stone. When stone is used, it usually functions as a base for elevations in wood or earth. What are the causes of such a comprehensive transformation in construction techniques? This change also affects the building of common houses in urban contexts, already begun in the transitional period.

The data so far collected seem to show Tuscany at the centre of a long-term economic evolution, of which the principal stages are as follows: first, a generalised crisis of the cities, that normally starts in the 3rd c., also affecting selected production centres in the countryside; then a marked deterioration of the city in the 5th c., accompanied by more restricted vitality in rural areas, though there were some short attempts to recover; a decomposition of both urban and rural habitats in the 6th c., though a few centres still show a certain prosperity, especially in the Valley of the Arno and in the Valley of the Cecina. These are rare exceptions to an economic panorama in which the thirty years of the Gothic War seem to be a watershed.

Between the 6th and the 7th c., Tuscan cities probably reached the lowest point of this recession. At this point they start to show differences between each other because some were chosen, and others were not, as centres with a military purpose. They have been classified into two fundamental models: 'shattered' cities (Lucca, Pisa, Firenze, Siena, Volterra and Arezzo) and 'fortress' cities (Cosa, Roselle, Chiusi, Fiesole). Nevertheless, excavations show that urban centres saw the same types of poor rural building and the same tendency to depopulation, with deserted zones alternating with nodes of nucleated settlement. In no single case (either in the city or in the countryside) can structures be recognised that emphasise families or individuals who had distinguished themselves as economically successful, for example by their houses and tombs, or by their domestic and ornamental artefacts. On the contrary, social levelling seems to have been the order of the day. It is not possible to recognise the presence of a significant market or of commercial flows or economic activities that show a relationship with its territory. The connection with the latter seems to have been interrupted for more than a century.

Poor building methods had spread already in the city from the 5th c. onwards, as well as in the countryside, though domestic construction techniques change radically with the period of the Longobards. The reasons for this seem to be many, and inter-related. There is a transition towards domestic buildings that were essentially huts, as Brogiolo and Gelichi have proposed,[17] in which one can recognise:

- the importation of Germanic models
- the re-adoption or persistence of rural building traditions
- the emergence of a domestic vernacular style, in which any Early Medieval farmer could construct his own house, from earth and wood that were universally available.
- a reliance on perishable materials that were now widely available, as a consequence of the reforestation that occurred after the decline and depopulation of the Late Roman countryside.

But the most remarkable characteristics of this transition are:

- the loss of the capacity to mix good mortars and to erect stone walls. The neglect of masonry techniques may have resulted in a massive reduction of knowledge, as one generation succeeded another, but not its definitive disappearance, as we know that inside the organisations of the *curtis* in the 8th and 9th c., there existed serfs who specialised in the construction of stone walls.
- the gradual replacement of tile coverings by roofs made of straw or something similar. This transition must be connected with the almost total disappearance of related kilns, though some local exceptions were perhaps occasionally used to produce tiles for specific monuments.

From excavations of Tuscan sites which later evolved into castles, it is now possible to suggest interpretative models with ever more detailed outlines of the characteristics of the topography and habitations of Early Medieval villages. In defining the components of the village, eleven types of feature can be identified, which can be connected with dwellings, stores, granaries, annexes, artisanal activity zones, courtyards, fences, palisades, streets, ditches and walls. This article will now consider some of the excavations of castles that were carried out by the *Area di Archeologia Medievale* in the provinces of Siena (Montarrenti, Miranduolo, Poggibonsi), Grosseto (Scarlino and Rocchette Pannocchieschi) and Livorno (Rocca di Campiglia and Donoratico) (figs 1–5). These contexts give us an opportunity to observe the birth and evolution of hut villages, and to propose some interpretations which might begin to give answers to the questions that we have suggested.[18] In terms of socio-economic reconstruction, there is evidence that the rural aristocracy's consolidation of power was a long process, of which we are now able to see archaeological traces from the Early Longobard period onwards. This is not visible in the construction of representative buildings or structures that are characterised by prestigious building materials, but through the traces of a more complex structure in the village itself, as well as in the organisation of work. Between the 8th and 9th c. the village was transformed by new planning and became a different type of settlement, even if building materials remained unchanged and dwellings continued to be huts. In almost all cases changes are observed which are definitively completed in the Carolingian period.

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[17] Brogiolo and Gelichi (1998).

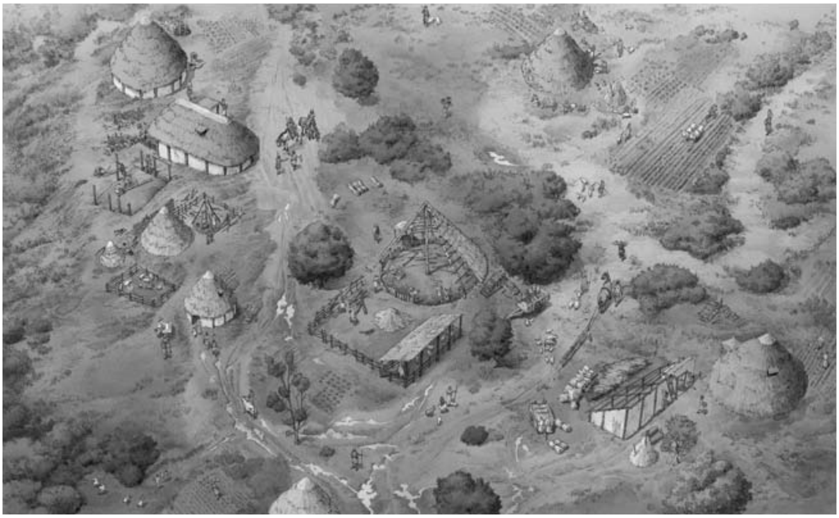

Fig. 1 Poggibonsi (Siena) is an imposing castle, situated along the Via Francigena between Florence and Siena. It appears in archive records from the mid-12th c. Excavation work has documented a first occupation phase in the late antique period and subsequently a large settlement of wooden dwellings growing up during the 7th and 8th centuries (drawing by Studio Inklink, Università di Siena).

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[18] See Valenti (2004) for bibliography.

In general, we can especially identify three major indicators: firstly, internal differentiation, with a spatial duality between a more distinguished space and a larger area, occupied by the rest of the farming families; secondly, changes in economic activities, with a marked evolution in agriculture and changes in sheep farming practices; thirdly, the consumption and accumulation of food supplies, which clearly differentiates families within the same community.

Domestic Buildings

Grubenhäuser

Grubenhäuser seem to have been used between the end of the 6th/7th c. and the 8th c. Examples are known from Poggibonsi and Donoratico. At Poggibonsi, the hut is dug out of the ground to a depth of about half a metre, is circular in shape and has a diameter of about 8 m. It was made of a wooden frame with earthen walls filling the space between perimetric posts. The ground plan and the presence of large internal posts, combined with the traces of holes outside the excavated perimeter, suggest the existence of a very high conical roof that was also at some points supported outside the outer wall. Access was via a sloping entrance, a kind of corridor that was also dug into the ground. The living space was divided into two aisles by a row of central posts. In one case, the presence of a wide rectangular cut with a levelled floor (2.60 × 2 m, 40 cm deep) should be interpreted as the position for a bed, designed to hold a simple straw mattress.

In Donoratico, a regular, circular *grubenhaus* (diameter 3.5–4 m, with an outer wall, consisting of at least 7–8 posts) has been discovered recently. It is not possible to establish the depth of the original sunken floor or the possible presence of a central post, because later changes have disturbed the area. Nevertheless, the living surface of the structure has been preserved, as has a possible fireplace, though its existence is not certain. In any case this must have been a hut that was only partially sunken (probably around *ca.* 40–50 cm below the earth), with posts arranged in a circle, and a roof resting on the ground. It probably served as a house.

The *grubenhauser*, or 'sunken-featured buildings', are still the subject of much discussion. Apart from the examples of Poggibonsi and Donoratico, others have so far been discovered at Brescia, Siena (beneath the

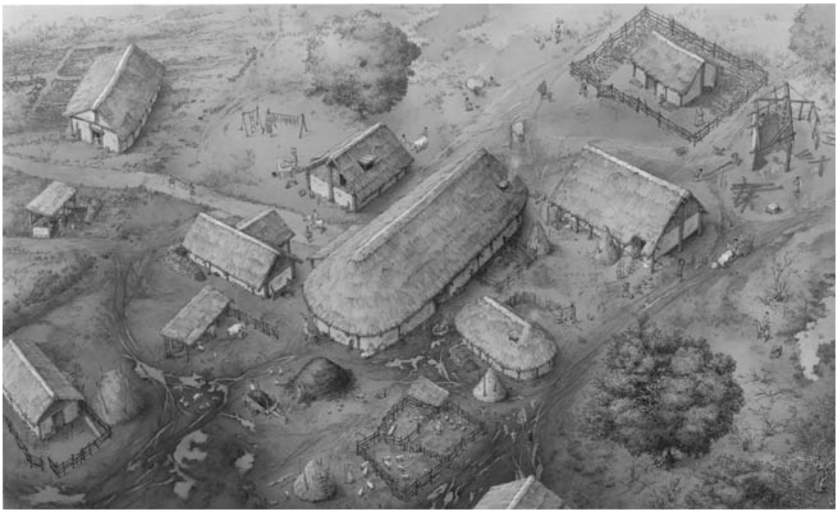

Fig. 2 Poggibonsi (Siena): the plan of the settlement was transformed from the mid-8th to the early 9th centuries; the settlement was reorganized in a curtis (drawing by Studio Inklink, Università di Siena).

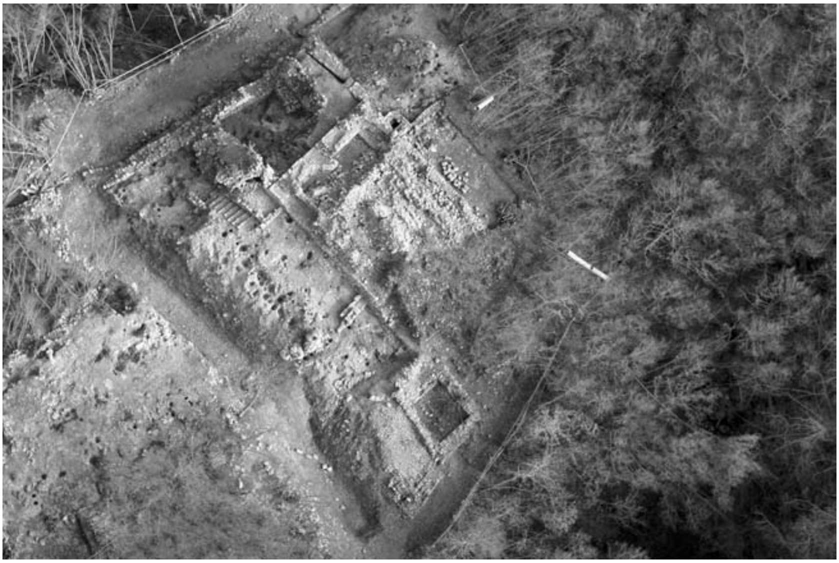

Fig. 3 Miranduolo (Chiusdino—Siena) The castello is documented from the early 11th c., and is about 20 km south of Montarrenti. The excavations are in their fourth season, and are uncovering a stable occupation of the hill which began in the 8th century and continued without interruption until the *incastellamento*.

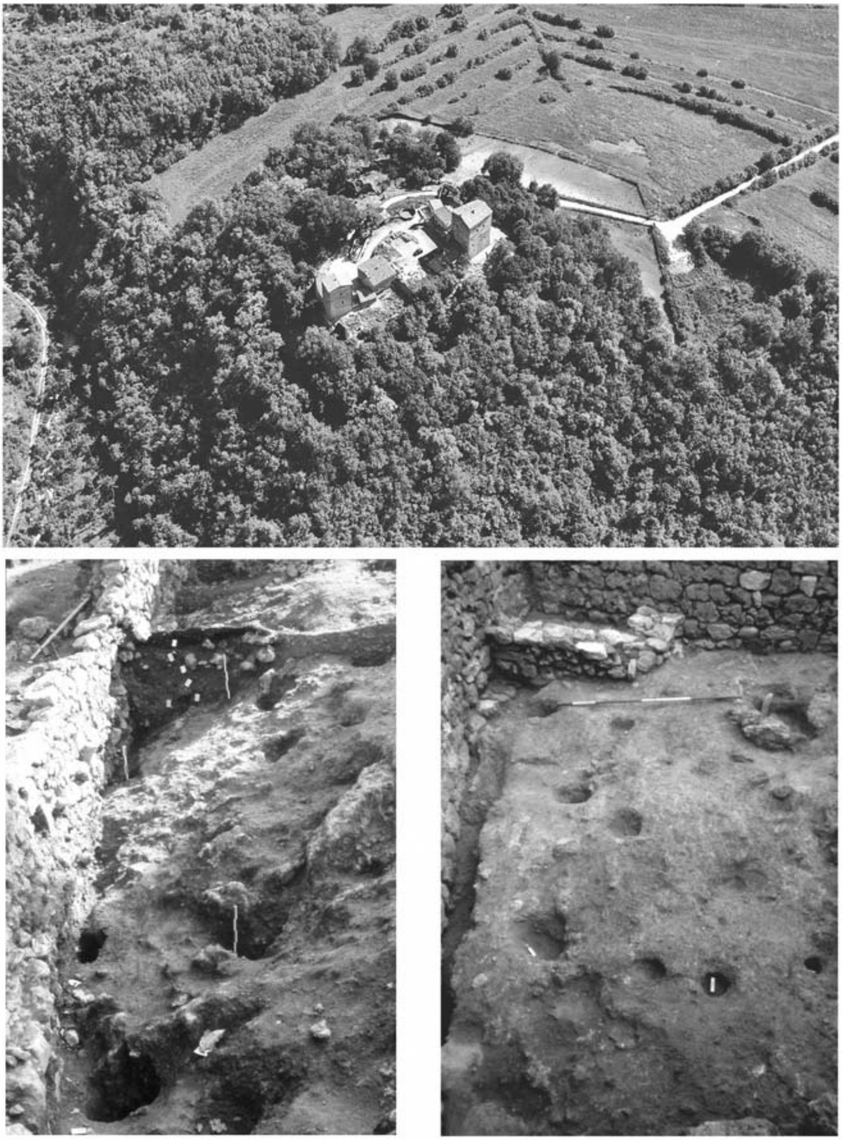

Fig. 4 The castle of Montarrenti (Sovicille—Siena) is documented from the mid-12th c. Excavations have demonstrated that the settlement began with a group of huts between the mid-7th and the mid-8th centuries.

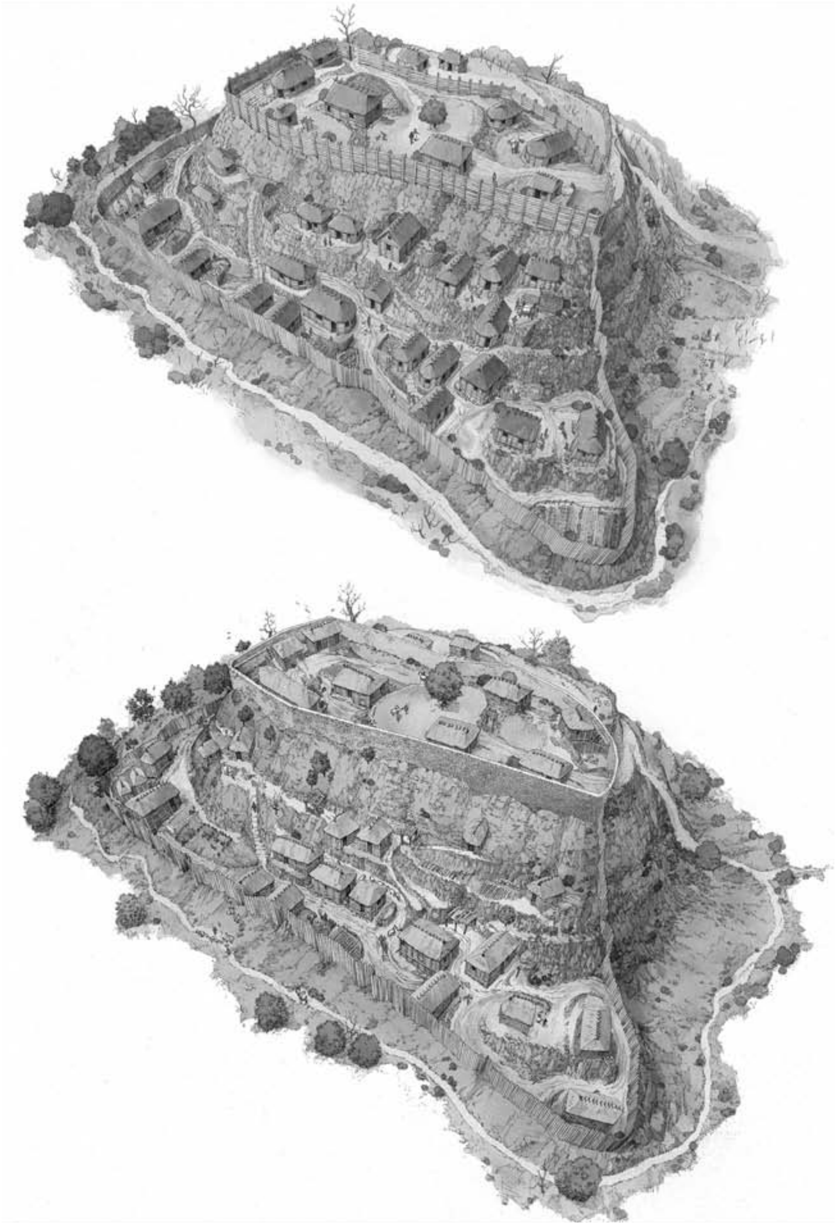

Fig. 5 Montarrenti (Sovicille—Siena) may have had two defensive palisades to fortify the lower and upper edges of slope. Between the mid-8th and 9th c. the upper zone was transformed: the timber palisade was replaced by a stone and mortar wall, and the dwellings were replaced by a large wooden, rectangular store (drawing by Studio Inklink, Università di Siena).

Duomo) and at Supersano, in the province of Lecce. All these structures, except that at Donoratico, are at the moment dated between the end of the 6th and the beginning of the 7th c.[19] They are very widespread in northern Europe. In the past, discussion focused on the organisation of walking surfaces and on the presence or absence of wooden floors. But now both of these arrangements have been revealed by excavation: occupation on the bottom of the hut, as well as floors of wooden beams. The space underneath the wooden floors was perhaps used as a cellar-storeroom (a hypothesis mainly based on comparison with some Danish and English houses). However, these *grubenhauser* should not be confused with similar partially sunken buildings (the *fond de cabannes*), that were used as small weaving workshops, which date mostly to the Merovingian period.

In Italy, two different interpretative models have been developed. The first (following the example of Brescia) tends to recognise the origin of these huts in the importation of Germanic models, by stressing comparisons with excavations in Pannonia.[20] Recent discoveries at Collegno in Piedmont (TO) seem to confirm this interpretation: amongst the structures where *grubenhauser* are present there are also Longobard tombs of the first phase.[21] The recent discovery of a graveyard at Frascaro in Piedmont can be added to these examples. The site has shown evidence of 17 burials, mostly with grave goods of Gothic context. Perhaps this case can as well be traced to Germanic parallels predating the settlement of Italy.[22] But as a result of discoveries in Lecce and the application of ethnographic parallels, a second model has emerged, which places these structures within the building traditions of humid regions, or areas with very poor climatic conditions: "such 'poor' or rural architecture... survived in specific environments within Italy from the protohistorical period until, at least, the Early Middle Ages".[23] The debate on this topic is not yet over, and will probably continue to evolve with the discovery of further examples, as too few have been discovered so far to resolve this question definitively.

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[19] Brogiolo (1992); Causarano, Francovich and Valenti (2003); Arthur (1999); Arthur and Melissano (2004).

[20] Brogiolo and Gelichi (1998) 132–33.

[21] Pejrani Baricco (2004).

[22] Micheletto (2003) and (2004).

[23] Arthur (1999) 175.

Timber-Framed Huts at Ground Level

Timber-framed huts built at ground level represent the most common variety of huts found, and exhibit a rectangular, elliptical or circular plan. These types are commonly found together on the same site.

1) *Rectangular plan*

At Scarlino, some huts have been uncovered that were used for a long period of time. Successive refurbishments are visible: older levels have been eroded or removed during the course of three centuries. At the beginning of the 10th c., two different size types of such dwellings were present (a larger one and a smaller one). In the area of excavation 'C', huts with sizes of 5 × 3.5 m have been revealed, while in sector 'A', an incomplete plan has been reconstructed, with dimensions of *ca.* 10 m × 4–4.5 m. Nevertheless, all the buildings were supported by posts, which were set into post holes, filled with loose soil and stones which acted as reinforcement. The material used in the walls has left no substantial traces, except for clayey concretions and accumulations of earth with high concentrations of carbon, in the abandonment levels. Drawing on these discoveries, one would not be far from reality to imagine elevations made of branches and covered with raw clay. The roofing of straw, which must have been kept together using vegetable binding (as there were no nails), was supported by a system of joints and dowels. The floors were constructed on a layer of levelled soil and can be related to walls in *pisé* found in Hellenistic buildings. Since these were made up of very silty, rammed earth, they were subject to progressive accumulation during the lifespan of the buildings, often allowing archaeologists to distinguish different floor levels. The fireplace was surrounded by stones and was positioned at one of the extremities, probably near the entrance, as no ventilation system has been attested.

The huts of Montarrenti are also set at ground level and are rectangular in shape. The smallest (in 'area 2000'), was occupied between the middle of the 7th and the second half of the 8th c.; it measured 4.5 × 2.5 m and covered a surface of circa 11 m^2. The perimeter posts of the timber frame were placed in holes that were dug out from the rock. Probably, the walking surface was the exposed rock itself, as it shows traces of levelling. In a second phase, the building was restructured by levelling the area even further, and by covering it with soil. The presence of a fireplace in the northern part is attested by four small stake holes, placed in the form of a square. Some internal posts, that are placed without a precise arrangement, should represent roof reinforcements, which seem to have been set at a slant. Between the end of the 10th c. and the beginning of the 11th c., three other rectangular huts of similar dimensions were built on the hilltop ('area 1000'). The smallest, of irregular shape, was composed of 10 post holes, and covered an area of 27.5 m^2 with dimensions of 5.5 × 5 m. The intermediate hut, regular in shape, consisted of 14 post holes and covered a space of 33 m^2, with dimensions of 5.5 × 6 m. The corner holes were large, and in the eastern part of the building a fireplace was set, surrounded by stones. The largest hut, defined by 12 post holes, covered an area of 37 m^2 and measured 7.5 × 5 m.

At Poggibonsi, a rectangular hut dating to the 9th–10th c. has been observed, of which the western side was slightly rounded and partially sunken, in order to counteract the slope of the hill. The hut has not been entirely preserved: a small part of the northern side has been lost. Nevertheless, it is possible to estimate a surface area of *ca.* 33 m^2 and dimensions of 6.9 × 4.8 m. The supporting structure is composed of a line of central posts and of stakes that constitute the outer wall. They are more or less regular, indicating good quality construction techniques. Close to the southern perimeter is a canal (3.4 m long), that may be related to a structural rebuilding or, more likely, to activities that were carried out inside the building. Thus the hut probably had both a residential and artisanal function.

2) *Circular plan*

At Poggibonsi, between the middle of the 8th and the middle of the 9th c., some huts were built of a wooden framework and a circular plan, with a diameter slightly greater than 8 m. They were demarcated by a circle of large posts (average diameter *ca.* 45 cm), which were placed at more or less regular distances (150 cm). We do not possess traces of the material that was used to build the walls, except for a few fragments of plaster and very thin layers of dust, perhaps a kind of sandy chalk mortar. This suggests the existence of a reed wickerwork covered with plastered earth. The straw roof must have had a very wide conical form, with a framework of beams, held together with vegetal bindings, and wooden rafters. The walking surface was made of rammed earth, resting on a chaotic pile of stones, *ca.* half a metre thick. The entrance was an opening in the north-western wall.

3) *Elliptical plan*

At Rocca di Campiglia, traces of huts are arranged along the edge of the plateau and can be ascribed to a period that definitely pre-dates the 10th c. The dimensions seem to be standardised (11–12 × 4 m) and they are subdivided into two aisles by a central alignment of posts which supported the roof. In Poggibonsi, elliptical huts are attested from the middle of the 8th c., until the end of the 9th/beginning of the 10th c. They have small and medium sizes, covering a surface varying between 20 m^2 and *ca.* 52–53 m^2. The posts, which constitute the outer wall, are inserted in a small trench dug into the ground. Medium-sized posts made up the elevations and in the trench, which was 28 to 30 cm wide, earth and stones were found, which were used for the fill of the walls. The absence of nails confirms again the extensive use of vegetal bindings and rafters. The covering was a saddleback roof and was supported in the interior by posts with a diameter of 25–30 cm, alternating with smaller posts with a diameter of *ca.* 15 cm. These were regularly arranged, along the limit of the interior, as well as being randomly-placed, closer to the centre of the dwelling. In other words, the roof was erected on the largest posts, which supported the greatest weight, and was laterally reinforced by a number of small posts. In some cases there was an internal hearth in the shape of a small fireplace resting directly on the earthen floor.

An exception to this group is a ship-shaped longhouse. It was a carefully planned building, partially sunken on one side, with dimensions of 17 × 8 m, thus covering a surface area of 136 m^2. The plan was established by excavating the southern long side and two short sides in order to level the slightly sloping ground. The northern section occupied an area where other huts had been situated before. It was built of a frame of wooden posts and earth walls, and showed a subdivision into three rooms: a domestic zone, a storage space and an area for mixed purposes. In the domestic zone, a hearth was constructed, consisting of a square base of earth/clay on which a framework of at least three posts was built. Grain was milled here, as is proved by the presence of a grindstone on the floor. A line of stakes in the the western part of the structure separated the domestic area from the storage space, where liquids and foodstuffs were stored in large ceramic containers, which were set into shallow holes. The grain was conserved in a silo of cylindrical shape. The roof was made of straw or another organic material and was of the saddleback type.

Huts with a Stone-Built Base

In the village of Scarlino, new dwellings have been constructed on top of the destruction layers of huts from a range of earlier phases. They are characterised by a mixture of stonework and wooden posts, and were probably finished using other perishable materials (straw, mats etc.). The foundations of the outer walls are made of small pieces of unworked stone and fixed by a binder that was composed of earth and organic remains, mixed with a crude lime. This was also used for the preparation of the floor levels. At least four buildings have been identified. The chronology of the ceramic finds of the destruction layers of this period suggests a date at the end of the 10th/11th c., thus in correspondence with the first documented mention of the *curtis*.

At Rocca di Campiglia this kind of structure is also attested in the same period. Here the buildings uncovered had a rectangular shape, measuring *ca.* 6 × 10 m, with foundations in blocks of unworked limestone, of medium and large size, which were bound together with an earth mortar. The buildings had two naves, with a central line of posts, that had regular dimensions and were reinforced by a clayish circle of earth and sand, as reinforcement. A possible hearth, set down on a rammed earth floor, though without any boundaries, was placed almost at the centre of the structure. As a consequence, the roof must have included a shutter that could have been opened to evacuate the smoke.

Finally, examples of a building of this type, once defined as *capanne in muratura* (stonework huts), have been found at Montarrenti, with the same chronology, and recently at Miranduolo, in coincidence with the transformation of the village into a castle.

Huts of Mixed Building Materials

Miranduolo is the only place where a hut built in mixed materials has so far been discovered. It can be dated between the end of the 10th and the beginning of the 11th c., contemporary with the *incastellamento* of the site. The dwelling leant against the surrounding wall and the rock-faces, and had a square ground plan with a single-pitched roof. The supporting function of some holes indicates a structure built in a mixed building style. The necessary inclination of the roof, made of perishable materials, suggests that the original height was determined by the same surrounding wall and, perhaps, the upper part of the rocky wall on the other side. Only on the west side do walls survive: these must have consisted of wickerwork covered with clay, as is proved by the plaster fragments that have been found. A circular fireplace was set in a big hole that was demarcated by stone pieces. The settings for large containers, which had already been installed here for a pre-existing hut, were reused and increased in number. All this would suggest the presence of a building with a double function: residence and the storage of food reserves.

Storehouses, Granaries and Functional Annexes

Storehouses

Storehouses are present in Poggibonsi and Miranduolo, but with different chronologies. At Poggibonsi, the building, which can be attributed to the Longobardian period, has a slightly trapezoidal shape and medium-small dimensions (longest base 3,5 m, smallest base 2 m, height 6 m). The supporting structure consists of a perimeter of posts, probably reinforced by an internal alignment of posts, set asymmetrically from the longitudinal axis. Such asymmetry suggests a roof that had one sloping side, tilted from east to west, with crossbeams laid on three lines of posts (on the two long outside walls and the interior asymmetrical wall). The elevations must have been executed in wickerwork covered by a clayey plaster (wattle and daub type). An internal cross wall, made of a wooden framework with a fence in reed, split up the structure into two rooms with different floor levels. The northern space, where the entrance was probably situated, seems to have functioned as a storehouse for the conservation of the foodstuffs, as it contained a partially sunken grain silo at the northern end. On the contrary, the southern room seems to have been used as a simple shed for storage.

The site of Miranduolo reveals a clear 'type' of storage building. Four structures with a storage function can be identified, from the study of archaeobotanical remains recovered on the site. The oldest building excavated so far is attributed to the period between the 8th and the 9th c., was circular in shape, measuring *ca.* 5 × 3 m, and was set where part of the rock had been cut out. For the greater part it was constructed of a framework of posts in oak and walls of earth, whereas in the western part there was an alignment of stones. Around the mid-9th c., it was replaced by a rectangular structure some 20 m^2 in size, with a northern wall made from a framework of posts, whereas on the east and south side the edges were formed by the rocky spurs. The building had a very steep pitched roof, which was supported by posts that were placed on the short sides and towards the centre. Other big holes accommodated containers for the preservation of food. Two successive floor levels were present, which both show the same kind of archaeobotanic remains and therefore suggest continuity of function. From the same period is a circular building (with diameter of *ca.* 6 m): a storehouse with a deep central pit like a 'cellar'. This was defined by post holes of medium size, sunken slightly into the earth by deliberate excavation; it must have been covered by a roof in perishable materials.

The last building to be discovered was made of mixed materials and can be dated to between the 10th and 11th c. It measured about 5.50 × 3 m, leaned on the south side against a rock-face, and was almost adjacent to the stone-built wall that surrounded the hilltop. This structure was built of earthen walls which rested upon a base in stone; the sloping roof was realised with slabs of schistose limestone.

The state of preservation of the archaeobotanical remains found at Miranduolo has allowed meticulous study; this is now beginning to provide interesting indications about the kinds of material that were chosen for the construction. A building of the mid-9th c. produced 1033 carbon fragments, of which most were of large dimensions (between 30 and 50 cm, so being large parts of crossbeams, posts, etc.). For the greater part, the storehouse was constructed using oak for the posts of the outer walls and the rafters, and probably using chestnut for the supporting crossbeams. Posts and crossbeams could be joined together by the use of withies of ash—a robust timber, both strong and flexible. The dowels for joints and riveting seem to have been of elm: a hard and heavy timber that is difficult to split and is generally used for carpentry. The presence of wattle walls or something similar, that were connected with the posts of the outer wall, seems to both proved by the presence of branches of wild prune, heather and hazel (a very strong timber, often used on the countryside to make hedges and generally mixed with hawthorn). The hazel, however, might also have had other uses. As a soft and flexible, but strong timber, it was commonly employed to produce mats and hurdles, to fix roofs in straw, to make baskets and coverings. Probably, it was also used for the production of containers that were used to preserve seeds and fruit, which were discovered in the stratigraphy (comprising a sample of 14,790 macro-remains). The absence of ceramics, except a few fragments without any connection, also suggests this, as do traces of sacks or bales (abundantly attested, for example, in the 10th c. storehouse). In the baskets, which were placed in the southern part of the building, hard wheat especially and, to a lesser extent, rye and barley, were preserved (amounting to almost 70% of the organic remains), together with small quantities of fruit, such as grapes, peaches, chestnuts, nuts, hazelnuts and olives. On the northern side of the building, however, products were stacked, which were meant for animal fodder (*ca.* 27% of the organic remains): pulses such as field bean and chickling vetch, together with acorns. Other kinds of timber, such as hazel, seem to relate to the existence of objects and tools. Hornbeam (very hard and strong) and maple (compact and small) may indicate the presence of tools made in this materials. Still today this timber is used for small turned objects and pieces. Sumac and smoketree, also present here, are shrubs that are largely employed for the tanning and dyeing of hides.

There are few examples of Early Medieval storehouses known so far from elsewhere in Italy. In particular, one should note that of Otranto (site Mitello), dated in the end of the 6th to 7th c. The storehouse has a rectangular shape, with foundations in unmortared stone and walls constructed in perishable materials, of which only parts of two sides have been discovered (the minimum dimensions of the building are 5.5 × 1.6 m). This structure was certainly connected with the artisanal district, which is present in this area, and could have been used as a depot for storing combustibles or for drying of jars.[24] On a European scale, however, there are many examples of storehouses. They can be rectangular in shape, with posts set at ground level, as well as circular or square, being partially sunken.

Functional Annexes

In the Carolingian phase of the village of Poggibonsi, a hut in the immediate vicinity of the longhouse was given over to butchery and the preservation of meat to be was consumed in the longhouse itself. It was a very simple structure, rectangular in plan, with medium-small dimensions (5.5 × 4.40 m), with one side slightly sunken. The north-western side was defined by cutting 10–15 cm deep, so that the ground was levelled, and the floor level slightly sunken. The supporting posts were regularly positioned along the perimeter, functioning both as connecting points for the walls built of earth, and also supporting a saddleback roof of the *Sparrendach* type. In fact, the roof rested on three crossbeams: one ridge-post, that was set on the two posts which were placed opposite each other in the centre of the short sides, and two lateral ridge-posts, which were laid on the lines of posts of the long sides. The entrance was dug out and had a rectangular, oblong shape (length 1.70 m, width 94 cm).

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[24] Arthur *et al.* (1992) 100.

Granaries

At Montarrenti and Poggibonsi, large granaries are dated to between the mid-8th to 9th c. and between the 9th to 10th c. respectively. The granary of Montarrenti was a large building, measuring 13 × 4 m, of rectangular shape, with a slightly rounded side. This structure was delimited by 26 post holes and had a large opening in the southern side. It was divided into three spaces, of which the central was smaller. The granary of Poggibonsi was rectangular in shape (8.5 × 5.5 m) and consisted of a framework of extremely robust perimeter posts, with a very dark floor level with clear traces of non-domestic occupation. North European literature has often associated this kind of evidence with granaries which have an elevated floor (intended to isolate cereals from humidity), and walls made of horizontal wooden planks and a saddleback roof.

The only granaries which have been discovered outside Tuscany come from Fidenza (Via Bacchini), dated to between the 6th and 10th c. A series of structures have been identified, which are made up of regular alignments of post holes, in association with well-preserved collapsed tree trunks that lack any precise order. Boxes used for the storage of cereals and fruit have been discovered, as well as a possible drying space.[25]

Fences, Roads, Artisanal Structures, Courtyards

Fences

At Poggibonsi, a village of 8th–9th c. date, there is a linear fence, composed of poles of medium and medium to small size (diameter

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[25] Catarsi Dall'Aglio (1994) 152–53.

10–20 cm), which are placed adjacent to each other. In some cases they are set in two lines. This fence extended in a north-south direction for at least 5.3 m, although a continuation in both directions is not excluded. It contains a centre of occupation, which developed to the east, and consists of a small path, running along the fence, and a habitation structure.

Examples of fences or enclosures are known from Piedmont (Monfenera and Centallo), Brescia, Lazio (Ponte Nepesino and Caprignano). At Monfenera (Vercelli), the excavation in a rupestral settlement has revealed occupation phases of the Late Roman and Early Medieval periods. In particular, an occupation dating to the 7th c. has been entirely exposed, that extends over about 30 m^2 inside the cave and over 37 m^2 on the outside. The adaptation of this shelter to habitation has been confirmed by the presence of poles, nailed fences, levelling activity and pits.[26] In Centallo (Cuneo), where a church and cemetery were occupied from the 6th to 10th c., a post-hole feature has been tentatively identified as a fence/palisade, which is difficult to date. Nevertheless, the considerable quantity of soapstone favours an Early Medieval date.[27] At Brescia-S.Giulia two examples of a fence have been recorded, marking the boundaries of domestic properties, dating from the mid-7th c. The enclosure of building XX is particularly clear: it consisted of an alignment of 6 post holes (average diameter 30 cm; depth *ca.* 70 cm), which were placed at a regular distance of 25 cm between each other. The holes must have contained sharpened poles, with a section *ca.* 20 cm square.[28] Also in Ponte Nepesino (Viterbo), a fence composed of four poles was built between the 9th and 11th c. It was located northwest of hut 4, for which it probably served as the enclosure. The post holes are set at a regular spacing (ca. 70 cm) and have an average depth of 40 cm.[29] In Caprignano (Rieti), a fence of 9th–10th c. date, next to a rectangular hut, has been interpreted as the border of a property.[30]

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[26] Brecciaroli Taborelli (1995).

[27] Molli Boffa (1986).

[28] Blake and Maccabruni (1985) 200–201.

[29] Potter *et al.* (1984) 90–91.

[30] Bougrad, Hubert and Noyé (1988) 438–39.

Roads

Two stretches of roads within villages have been recognised from the excavation at Poggibonsi. The first is related to the village of the 8th–9th c. It is preserved for a distance of 6 m, measures about 1.60 m wide and is constructed of rammed earth. This was a path inside the settlement, running along one side of a fence of small and medium sized poles, and on the other side past a dwelling hut. The second stretch of road relates to the 9th–10th c. village, and is connected with the longhouse. It is in fact a long sloping corridor of rectangular shape, adapted to the shape of the local terrain, being 44 cm wide and dug out of the ground, with raised parapets and small drains for the evacuation of rainwater. It remains doubtful if this corridor was covered by wooden boarding, as is suggested by more common parallels in North-Eastern Europe. Credible traces of such boarding have not been identified here, though some layers were rich in carbon. At Peveragno (Cuneo), another road stretch has been recognised, in a sequence of three layers, which filled a ditch.[31]

Well-preserved examples of road systems come from Denmark. In Grønbjerg, the road system on the western side of the central part of the settlement was raised up, between the second half of the 10th and the beginning of the 11th c., to avoid problems caused by frequent flooding. The secondary road system consisted of paths in rammed earth, which were slightly cut into the earth. A final street with a wooden pavement connected the embankment with the main road system.[32] In Vorbasse, a road in rammed earth was constructed between the first half of the 8th and the second half of the 10th c. This street, 8–10 m wide, was oriented east-west and preserved along the whole excavated area, for a distance of about 40 m.[33]

Artisanal Structures

In Montarrenti, an oven for drying corn was present between the middle of the 8th and the 9th c. It was constructed on a base of stone and clay, with cap-shaped elevations made in yellow clay and covered by a shed that was erected using 8 post holes.

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[31] Micheletto *et al.* (1995) 151.
[32] Nielsen (1979) 174, 198.
[33] Hvass (1979) 150–51.

A pottery kiln is attested in Poggibonsi between the middle of the 8th and 9th c. It had a cylindrical shape and consisted of a brick cupola, surrounded by a reinforcement of stones, pebbles and other fragmented bricks. The mouth was placed upon two squared building stones, and the walls show considerable traces of blackening by fire. Although this is probably a re-used water reservoir dating from Late Antiquity, the elements which establish its interpretation as a kiln are very clear: a large quantity of terracotta spacers were found, as were numerous layers with heavily burnt soil, which lay over it. The stratigraphical sequence of the structure confirms that it was used at the same time as the longhouse.

Forges for metalworking are attested in Rocchette, Rocca di Campiglia and Poggibonsi in the 9th and 11th c. They all represent the same kind of stratigraphy: layers composed of congealed earth and stones, charcoal, ashes and slag. The stratigraphy at Poggibonsi is composed of: an alignment of north-south oriented poles (ca. 2.60 m); an occupation level, heavily blackened and rich in organic materials; the remains of charcoal and brick fragments (size 4.1 × 4.3 m); and of a pit in the southern part, with a diameter of *ca.* 1.30 m, which contained slags. Of the latter feature, only part has been preserved because it was cut by a Late Medieval wall. Along the northern side of the occupation level there is a linear feature cut into the ground, which can probably be interpreted as a small drainage canal connected with the artisanal activities. The kiln had a hood, made of stones and bricks, which was coated with clay, and was covered by a shed; this was probably 4 × 2 m in size and partially closed on the northern and eastern sides by low earthen walls set on a stone foundation.

Courtyards

During the 9th–10th c. phase, an open space of more than 400 m^2 stretched north of the longhouse of Poggibonsi. This area is bounded to the north by a possible dwelling-hut, to the east by a covered area/fence for animals, and to the south by two small huts and by the longhouse itself. There is no clear limit on the western side. However, the alignment of the structures of the whole village along the Late Medieval road, suggest the existence of a street inside the village. This could have demarcated the open space from the Carolingian age onwards.

Numerous activity traces, which will be described below, allow us to interpret the area as the courtyard of the village.

The rectangular covered area (5.1 × 2.1 m) probably functioned as a shelter for animals. A regular line of poles immediately south of this structure can be interpreted as a fence, also connected with breeding activities. It is, however, also possible that the covered area and the line of poles form part of one single structure of larger dimensions. Numerous small holes, which cover much of the area in a disorganised fashion, probably represent temporary stakes. It is more difficult to interpret three larger holes, in which fragments of large ceramic containers have been found. Probably these were small silos for the preservation of foodstuffs or drinking troughs, related to the covered area.

A series of medium-small holes, set in several different lines, are located in the central-western part of the open space. These are very probably the remains of one or more fences, which only had a temporary character. They were frequently rebuilt, and the geometry of their plan was often changed. These structures probably also served as animal shelters. This interpretation is confirmed by the presence, immediately to the east, of a waste area (surface area of *ca.* 10 m^2), which was distinguished by the highly organic composition of the soil and by some post holes. The area can probably be interpreted as a dunghill or rubbish dump for refuse connected to the agricultural activities of the village.

The south-western zone seems to show other characteristics. Some irregular and larger holes (up to 1.20 m in diameter), with traces of congealed clay (perhaps serving as small fireplaces in the open air) and lime stains (plaster?) seem to relate to activities that were carried out in the courtyard. Other features characterise the open space as a courtyard. The numerous small post holes, spread throughout the whole open area in a random manner, can be related to temporary structures connected with agricultural activities and breeding (such as poles to tie up animals, haystacks, piles of wood, etc.). At least two fireplaces are located in the central part of the area. Stains of congealed clay, dark earth and soil with carbonised inclusions, provide evidence that a great variety of activities were carried out in this zone.

PALISADES, DITCHES AND WALLS

Palisades

Examples of palisades are attested at Montarrenti and Miranduolo, which were, in both cases, later replaced by a stone wall.

At Montarrenti, a stockade of poles was built between the middle of the 7th and the middle of the 8th c., which separated the hilltop from the slopes of the hill. The palisade followed the contours of the site and consisted of large posts that were arranged by symmetrical pairs, which perhaps supported other poles or horizontal beams. A second palisade of the same date may have defended the lower part of the village. Of this, only five large post holes have survived.

At Miranduolo, where excavations are still in progress, the existence of a large timber palisade, surrounding the whole hilltop, is attested in the 9th c. At the moment, it has been discovered in two areas (north and east). In the northern area, a ditch 60 cm deep and 1 m wide was dug out in front of a steep precipice. A series of medium-sized poles was then set into the rock, fixed in their postholes with a filling of earth and crushed stone, derived from cutting into the rock. Seven holes have been detected that were aligned in an east-west direction. In the western area, ten other poles holes of large size have been discovered, running for a distance of 20 m. There are clear signs of reuse, which can be connected with a refurbishment of the palisade.

Other examples of defensive stockades are attested in Liguria and Piedmont. At *Castrum Pertice* (Finale Ligure), a palisade was set into large post holes, which were dug straight into the rock. It was located on a rocky terrace on the hill, slightly behind the position occupied by a later enceinte. Behind the palisade lay an embankment, which was connected to the hill. An alignment of unmortared unworked stones was placed at the foot of the embankment, in order to act as a retaining wall. The stockade predates the enceinte, which dates to the late 6th-early 7th c., against which leant wooden dwelling structures.[34] At Treonzo (Alessandria), a linear palisade has been dated to between the 5th and the 10th c.[35] Ten post holes were found spaced at regular intervals, with some interruptions. The palisade extended 40 m in an east-west direction, though with at least two minor changes of direction, to adjust to the morphology of the hill. The author, Giannichedda, suggests that the 'Ständerbau' construction system was used, a sort of early half-timbered technique with horizontal beams strengthening the vertical posts and forming a robust wooden framework.

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[34] Mannoni *et al.* (1990) 431; Mannoni and Murialdo (2001).

[35] Giannichedda (1990) 274–76.

Ditches

The only examples of Early Medieval ditches known at the moment come from Miranduolo, where the evidence is set around the hilltop. The western ditch, of which the excavation is still in progress, is dated to the 9th c., and was 7 m wide and 33 m long. Its depth has been established as about 3 m, though the proposed dimensions are not yet definitive. In fact, we still do not understand if the ditch was widened and deepened when the castle was constructed, or not. The holes of the palisades on this flank of the hill were dug straight out of the rocky slope, which makes up one of its sides. The digging of the holes in correspondence with the ditch emphasises that the latter was realised together with the fence, though it is also possible that the ditch already existed before the pallisade was set, and was connected to the pre-existing village.

Ditches in Early Medieval contexts are attested in Piedmont, Lombardy, Emilia Romagna, Lazio, Abruzzo and Puglia. At Treonzo (Alessandria), topographical research has located a fortified site, dated between 7th and 10th c., that was built on several terraces, which were created by levelling the rock through cutting off small sections. Towards the ridge on the west side of the hillock, the settlement was defended by an artificial trench that was more than 4 m deep in the central section. On the western side, two hollow niches have been interpreted as the supports for a footbridge, something like a drawbridge.[36] At Castelseprio (Varese), the church of Santa Maria *foris portas* was also provided with a defensive ditch, 5 m wide and 3 m deep, which was used for only a short period. This observation has a lot of parallels in written sources, from the 9th c. onwards, as well as in modern archaeological excavations.

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[36] Giannichedda (1990).

The church of San Tomè of Carvico was supplied in its last phase with a defensive structure, consisting of a ditch with an embankment.[37] Cittanova (Modona), a fortified settlement interpreted as a bishop's residence, is generally dated in the 9th–11th c. It had defensive structures, consisting of a ditch with an artificial embankment and a metalling made with broken brick pieces.[38] At Imola—Villa Clelia (*Castrum Sancti Cassiani*), a building identified as the late antique cemetery basilica of San Cassiano was defended in the second half of the 6th c. by a surrounding wall with a ditch. The discovery of a coin on the bottom of the ditch indicates continuity in use until the period between the end of the 10th and the beginning of the 11th c.[39] At Sant'Agata Bolognese (San Giovanni in Persiceto), the village is surrounded by a quadrangular fortification; the site can probably be identified as the *castrum Pontilongi*, which is mentioned in documents of the 10th and 11th c. It consisted of a small nucleus of habitation surrounded by a fence of vertical stakes and a wide ditch on both sides of the wooden structure.[40] Recently, the excavation near the monastery of Nonantola, still unpublished, has revealed the presence of a ditch that can be dated in the 10th c. It must have been 15 m wide and 2 m deep, with slanting faces of a gradient of *ca.* 45°.[41]

In the 8th c., Castel Porciano was a settlement situated on a small hill (25 × 25 m), provided with two defensive lines, although the site had strong natural defences. A ditch 3 m wide was dug on the southern side, corresponding with the narrowest point of the hillock. A small stone tower (3.75 m wide) was constructed in tufa blocks, and was faced by a second ditch, to protect the main entrance to the village.[42]

At Casale San Donato (Rieti), an Early Medieval feature (ca. 1.5 m long 2.6 m deep, 1.2–1.7 m wide) was cut, which had almost vertical sides; this has been interpreted as a ditch. It is contemporary with a platform that was created by levelling bedrock and bordered by a wall on the southern side.[43] At Astignano (*Castrum de Lesteniano*, in Pescara), traces of a probable ditch have been attributed to the Early Middle

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[37] Brogiolo and Gelichi (1996).
[38] Gelichi *et al.* (1989).
[39] Gelichi *et al.* (1990).
[40] Gelichi and Giordani (2003).
[41] I owe this information to Sauro Gelichi, to whom I am very grateful.
[42] Potter (1985) 170–73.
[43] Moreland *et al.* (1993).

Ages.[44] At Specchia Schiavoni (Taranto), a ditch was cut into the rock sometime in the 7th to 8th c., with a width between 6 and 6.5 m and a depth of about 3 m. Numerous scattered stone blocks, found in the area, probably belong to a wall that ran parallel to the ditch itself; the structure ended close to a carriageway. This complex has been recognised as one of the defensive installations created by the Byzantines to block the advance of the Longobards.[45]

Walls

Three sites, Montarrenti, Scarlino and Miranduolo, have produced evidence of stone fortification walls, that can be dated in the Early Middle Ages.

Between the middle of the 8th and 9th c., the wooden palisade of the hilltop area of Montarrenti was replaced by the construction of a wall. This new defence was set straight onto the rock, and was realised in large, roughly squared stones, that were fixed by a yellowish mortar. It underwent a sudden demolition that affected even the foundations, but it was reconstructed.

Along the south-western slope of Scarlino, a thick wall was built in the course of the 9th c. This structure was made of rough stones, which were joined by earth, and can be identified as a surrounding wall. However, the reconstruction of its course and its eventual elevation are problematic. It cannot be excluded that this was realised with a palisade, hedges or other systems, and it may have coincided with the outer walls of buildings in stone and wood. The topographical relationship between the dwellings along the south western edge and the wall, that lies a bit lower, seems clear, but we cannot be sure that these elements were contemporaneous.

At Miranduolo, a stone wall has been traced in the northern excavation area, along with its foundation trench, with a few surviving stones, in the western part. The surrounding wall was 1.30 m thick and was constructed with split and roughly shaped pitted limestone blocks, which were placed in horizontal layers. The binder was tough and yellow, and composed of fine sands and lime. The exact date of the palisade is not yet known; a wide range of carbon samples were collected during the excavations, and are at the moment being processed for radiocarbon dating. But we can possibly date the surrounding wall in the course of the 10th c., especially as a *terminus ante quem* is provided by a new wall that was erected upon the foundations of this earlier structure. The new defences can probably be dated between the end of the 10th and the beginning of the 11th c., because of their characteristics: unworked, split limestones placed in an irregular arrangement of quasi-horizontal layers. This chronology is similar to an analogous wall at the nearby castle of Rocchette Pannocchieschi, and at the castle of Gorfigliano, a village in the Garfagnana area.

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[44] Staffa (1994) 84.

[45] Stranieri (2000) 333–35.

The 8th–10th C.: Formation and Transformation of the Early Medieval Village

Between the end of the 6th and the 8th c., nucleated settlement forms appeared in Tuscany to the detriment of existing late antique settlements, which were characterised by villas, *vici* and scattered houses, that gradually disappeared. The origins of Early Medieval nucleated settlement can be sought in the spontaneous choice of rural families to live gathered together: there is no evidence of any kind of social hierarchy or signs of power in the many excavated villages, of any centralized control of agricultural and artisanal activities or of food storage, or of any diversification in the quality of food consumption. Surface surveys highlight that the dispersed rural settlement played a very marginal role, or even none, contrary to what has been claimed by models based on written sources. The formation of the new settlement network seems to originate, more or less, from around the years of the Gothic war, and continues into the first decades of the Longobard conquest. Its development must be due to the economic and military difficulties of these decades and, above all, the need to manage better a damaged countryside, that had been recolonised by nature, through collective effort. Hilltop zones were preferred (as at Scarlino, Poggibonsi, Donoratico). Sometimes flat areas (e.g. San Genesio) were used, if sites were reoccupied that had been more or less continuously inhabited in Late Antiquity and which had only been abandoned for a short period. But the superimposition of agglomerations of huts on ancient sites should not be taken as evidence of the existence of owners who were still active in reorganising the remains of their property. This explanation seems very doubtful to us on the basis of the archaeological and anthropological data, and also because of the weakness of local political authorities ruling Tuscan cities and the countryside between the middle of the 6th and the beginning of the 7th c.

Now we feel inclined to interpret the sites excavated in the Tuscan countryside[46] as nucleations of agricultural families determined to organise their farming land better: a concentrated settlement made it easier to carry out extensive agricultural exploitation, to apply crop rotation and to best exploit complex agricultural tools. The attested economic activities reveal an initial specialisation of animal breeding and a progressive development of agriculture.[47] Such villages did not require the direct management of a land-owner or one of his confidants/agents. Perhaps such people resided in other places, but in fact it is not easy to envisage even this; there is a general lack of material evidence connected with indicators of aristocrats, who supposedly resided in the cities, or with peripatetic owner-consumers, who travelled about from one centre to another.

In a second phase, these settlements seem to transform themselves into centres that regulated work, in such a way that they reorganised power around a local base. The material evidence reveals a slow transformation of the village in the course of the 8th c., and a definitive evolution into the *curtis* village between the 9th and 10th c. Structures were appearing which coordinated production. Earlier these features were absent. They can be recognised through the topographical and functional evaluation of groups of structures, which can be easily identified and represent anomalies in the uniformity of the settlement. They manifest themselves as a block of buildings that are sometimes defended and concentrated around an open space. In these structures, rooms can be identified that are destined for the storage and preservation of foodstuffs. The successive and progressive transformation into *curtes* gave rise to other quasi-'urban' developments, with an even clearer definition of the area of the *dominus*.

The consolidation of the power of rural aristocracies thus seems to have been a long process, of which we have succeeded in grasping an archaeological trace only from the Early Longobard period onwards, and more distinctively in the Carolingian age. Then a decisive change took place, which can been seen in the presence of an internal hierarchy that significantly characterises the topography of settlement centres. Between the 8th and 9th c., the rural elites confirmed themselves in a definitive way because they managed to control/subjugate the rural population and to consolidate their own properties. At the same time, distinctive zones appear on excavated sites, which clearly reveal a more complex articulation in the interior of the village, as well as in the organisation of work. Finally, the presence of a *dominus*, or one of his representatives, becomes tangible. The changes that took place in pre-existing centres and the manner in which many were founded later, could by consequence represent a sign of the concentration of the land around the villages in the hands of a single subject.

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[46] Scarlino, Montarrenti, Poggibonsi, Miranduolo, Rocca di Campiglia, Donoratico, Rocchette Pannocchieschi, Cugnano, Montemassi and Staggia, to mention only the cases studied in the area of Siena.

[47] See Francovich and Hodges (2003).

The role of religious buildings is still to be determined. Were they, or were they not, pivotal in the formation of settlements? The presence of churches that spread throughout the countryside, from the late antique period onwards, is indisputable for the whole of Italy. Nevertheless, a rural church has never been systematically excavated in Tuscany. As elsewhere, their importance has to be determined archaeologically, as does their connection to settlement contexts. The impact of churches on population processes might have been insignificant, as during the major demographic crisis between the 5th and 6th c. The simple superimposition of complexes of the villa-church type on the same site cannot be interpreted as a continuation of settlement or as indicating that churches played an important role in the organisation of the countryside; such a statement could be accepted only if a number of consistent contemporary structures are found in areas adjacent to the church, giving us the possibility to catch a glimpse of a settlement centre.

Significantly, religious buildings were absent between the 7th and 10th c. in villages that have been identified underneath castles, except at Scarlino in the 9th c. and perhaps at Donoratico in the 9th–10th c. In the formation of these centres, the first preoccupation was certainly not to satisfy the religious needs of the population, but to achieve a 'biological mass' of adequate consistency. Below this minimum, the community could not easily reach the critical mass that would be needed for effective agricultural production at subsistence level. It is likely that existing churches, for which we do not know the occupation history, were used by a number of settlements located in the neighbourhood which were formed from the end of the 6th and the 7th c. onwards. It was not the settlement network which modelled itself in relation to the existing churches, but the contrary.

In the Carolingian period, analysis of villages beneath Tuscan castles reveals the productive organisation of this period. The *curtis* inserted itself in, and adapted to a system of pre-existing rural settlements, which were transformed into quasi-urbanised centres by the reorganisation of a lord—through different spatial layouts of the 'classical' division, between *pars dominica* and *pars massaricia.* With the passage towards the *curtis* economic model, inhabited areas underwent clear spatial re-planning and the organisation of labour seems also to have changed. From a settlement topography perspective, examples emerged of domain estates of the *dominus* (*dominica*) and outlands (*massaricia*) that were adjacent to the settlement centre (Montarrenti, probably Scarlino, Miranduolo and Donoratico) and other outlands that were separate from it (perhaps at Poggibonsi and especially at Campiglia). Actual seats of power were very organised complexes, sometimes defended, physically separated from the farmers' houses and located in the centre of the settlement (Poggibonsi) or on the hilltops (the areas enclosed by palisades in Montarrenti and Miranduolo; the space surrounded by a wall in Scarlino if a *massaricium* was present on the unexcavated parts of the site; the internal division of Donoratico).

The appearance of the village also changed with the construction of buildings (storehouses and granaries directly connected to the privileged part of settlements), which reveal the presence of an owner who enjoyed a better quality of buildings and a better quality of material culture in comparison to the rest of the village. This person was able to organise the collection of the agricultural dues (attested in documents or suggested by faunal remains), as at Montarrenti, Poggibonsi, Miranduolo, probably Scarlino; he was able to concentrate buildings which produced goods, such as forges and kilns, as at Montarrenti and Poggibonsi, and probably at Donoratico and Rocchette, and to concentrate buildings which processed foodstuffs, such as kilns for drying cereals, or structures for grinding, or buildings for butchering and preparing meat, as at Montarrenti, Poggibonsi, Donoratico; he was able to require services from farmers, such as the erection of palisades or walls, and the digging of ditches, as at Montarrenti, Miranduolo, and perhaps Scarlino, or to recruit specialised workforces for specific projects, such as the construction of the church of Scarlino.

The house of the *dominus* can be described as a rather small residential area, organised around the dwelling of the lord or of one of his agents, such as the longhouse at Poggibonsi, the large huts at Scarlino and Miranduolo. This building was surrounded by storehouses and granaries, yards, cowsheds and fences for animals, and by functional structures for the production of manufactured goods, or for the working and treatment of agricultural products. Ceramics do not seem to help greatly in understanding the economic and social characteristics of settlement centres. To building features can be added data derived from the study of animal bones and archaeobotanical remains, which reveal not only different economic strategies but also the existence of hierarchical and economic relationships, their characteristics, obligations and limitations. Food is one of the clearest indicators of the presence of social differentiation. The way in which meat was distributed is especially interesting. At Poggibonsi, for example, it raises the *dominus* above his dependents, with a further difference between the quality of the meat parts consumed in the longhouse and in the other huts; this is yet another indicator of the presence of different social and economic roles within settlements.

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Fig. 1. Poggibonsi (Siena) is an imposing castle, situated along the Via Francigena between Florence and Siena. It appears in archive records from the mid-12th c. Excavation work has documented a first occupation phase in the late antique period and subsequently a large settlement of wooden dwellings growing up during the 7th and 8th centuries (drawing by Studio Inklink, Università di Siena).

Fig. 2. Poggibonsi (Siena): the plan of the settlement was transformed from the mid-8th to the early 9th centuries; the settlement was reorganized in a curtis (drawing by Studio Inklink, Università di Siena).

Fig. 3. Miranduolo (Chiusdino—Siena) The castello is documented from the early 11th c., and is about 20 km south of Montarrenti. The excavations are in their fourth season, and are uncovering a stable occupation of the hill, which began in the 8th century and continued without interruption until the *incastellamento*.

Fig. 4. The castle of Montarrenti (Sovicille—Siena) is documented from the mid-12th c. Excavations have demonstrated that the settlement began with a group of huts between the mid-7th and the mid-8th centuries.

Fig. 5. Montarrenti (Sovicille—Siena) may have had two defensive palisades to fortify the lower and upper edges of slope. Between the mid-8th and 9th c. the upper zone was transformed: the timber palisade was replaced by a stone and mortar wall, and the dwellings were replaced by a large wooden, rectangular store (drawing by Studio Inklink, Università di Siena).

UMAYYAD BUILDING TECHNIQUES AND THE MERGING OF ROMAN-BYZANTINE AND PARTHO-SASSANIAN TRADITIONS: CONTINUITY AND CHANGE

Ignacio Arce

Abstract

This paper analyses the introduction, merging and use of building materials and techniques, architectural typologies and urban patterns, during the Umayyad period in *Bilad al-Sham* (present day Syria, Palestine and Jordan), within the general framework of the cultural interchange that took place in that period between eastern and western traditions. For most of its history, and especially in Antiquity, this was a frontier area, or a *buffer zone* in modern terms, between the main regional powers: Egypt and the successive Mesopotamian empires; Persia and Greece; the Seleucid and Ptolemaic kingdoms; Rome and Parthia; Byzantium and the Sassanians. As a result, it not only witnessed war, invasion and destruction, but also fruitful economic and cultural interchange. This frontier was lifted twice: first, during the reign of Alexander, and, secondly with the rise of Islam.

Introduction

After a military campaign launched against the Emperor Phocas in A.D. 607, the Sassanians over-ran the *Limes Arabicus* in 611 and ravaged the north of Syria. In 614, they captured Palestine and Jerusalem, carrying off the Holy Cross as war booty to their capital, Ctesiphon. Shortly after, they captured Egypt. It took the newly-proclaimed emperor, Heraclius, until 622 to react and raise an army to recover these lost but vital territories. He reached the heart of the Sassanian Empire in 628, from which he brought back the plundered relics, and regained Jerusalem two years later.

The weakening of the eastern frontier had started a century earlier when, during the reign of Justinian, the army abandoned the fortifications built along the *Limes Arabicus*. In their place, local, Christianised

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Arab tribes—at first the *Banu Salih* and, afterwards, the *Ghassanids*—were entrusted with its defence, as *foederati* of Byzantium.[1] The subsequent long-lasting wars, religious conflicts and political crises induced instability and general unrest in Late Roman Syria, which was worsened under the despotic reign of Phocas and would never be fully resolved. For these reasons, Islamic expansion encountered almost no resistance; Byzantium was still weak, even after regaining the territories lost to the Persians, whilst the defeated Sassanian kingdom had barely survived. The fate of Bilad al-Sham was sealed in A.D. 636 at Yarmuk. Mesopotamia and Persia surrendered after the battle of Qadisiyyah in 636. The final defeat of the Sassanian kingdom followed a few years later, in 642, at Nahawand near Merv. The last *Shah*, Yezdigird III, was assassinated in 651.

Thus, following the Arab conquests, the frontier between the two 'superpowers' of the antique Middle East, between the East and the West, ceased to exist. The area now became the centre and capital of the new Umayyad power for about a century. Byzantium would recover and become the sole power opposing the advance of Islam in Anatolia, whilst the Sassanian Empire disappeared forever. This political and military context helps us to understand the success of the emergent Muslim power under the first 'orthodox' and, subsequent, Umayyad, Caliphs, and the references and models adopted and developed by their new culture thereafter. As I will discuss below, these affected all aspects of the cultural life of this new society, in particular, the development of architecture and urbanism.

A New Image of Power

Throughout history, rising powers have caused the downfall of other consolidated, highly-developed empires. They have subsequently imitated, adapted and transformed the pre-existing cultures of their predecessors. The new Umayyad Caliphate had both the Byzantine and the Sassanian empires to draw upon; an ambiguous situation that would eventually create political and administrative confusion in, for instance, the bureaucratic system: in Syria, Greek was the official language, while in Persia and Mesopotamia, Farsi (Palhevi) prevailed. Similarly, both of the pre-existing monetary systems were maintained, posing a genuine threat to the political and economic authority of the new state.

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[1] Similarly, the Sassanians relied on the *Lakhmids* for the defence of their desert frontier.

This chaotic situation was worsened by the difficult struggle the Umayyads faced to establish their control over the Caliphate. They were only able to fully secure their power under the reign of Marwan I, founder of the *marwanid* branch of the Umayyad family, who is known to have replaced, not without protest, the electoral system of the Caliphate with a hereditary one. His son, Abd el-Malik, introduced further reforms that ensured the economic and administrative control of the new State, and produced the required political stability: he unified the administration, promoted Arabic as the official language of the public court, or *Diwan*, and reformed the monetary system, which would soon become the standard system in the Mediterranean basin. Moreover, he acknowledged the importance of architecture and urban planning in creating symbolic supremacy and effective control over the newly-conquered territories. In fact, the building of new cities had already started with the first conquests: Caliph Omar, who is considered by many to be the real father of the Islamic state, had founded strategic sites at Basra, Kufa (in Iraq), and Fustat (in Egypt).

In contrast to the Byzantines and the Sassanians, the Umayyads still lacked well-defined protocols for ceremonial occasions, and symbols of power. The need for a protocol of display and the availability of the two preceding models presented a difficult choice. The Sassanian tradition was more suitable for re-use, given that it had been released from its political meaning and symbolic associations, belonging as it did to a vanquished kingdom.[2] In contrast, Roman elements would prove to be far harder to incorporate as, although weakened, the Roman Empire was the surviving power still opposing the Umayyads. Therefore, the Umayyads erected palatial and monumental buildings to rival the symbolic, fascinating and magnificent Christian churches, and other similar Roman monuments in the region, the monumentality and number of which were constant reminders of the power of the surviving Byzantine tradition.

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[2] As part of that pragmatic approach mentioned above, old forms and spaces were eagerly re-used by the new rulers, although they were sometimes modified. For instance, even though the Umayyad decoration of arches clearly originated in Sassanian custom, highly symbolic elements, such as the crescent at the apex of the arch, and the hairknot with the royal scarf at the springing line, have disappeared. See Arce (2001a) and (2001b).

Since a swift and effective reaction was required, the Umayyads solved their problem in a very pragmatic way: they began to merge the cultural traditions of the vanquished empires, optimising existing resources, and mixing typologies, forms, materials and techniques. Thus, they created an entirely new culture including, in particular, an innovative architecture that was completely different from its predecessors, and had a strong and vigorous identity.

Adoption of Urban and Architectural Typologies

The swiftness of the Arabs' conquest and their need for territorial control, meant that they required simple and efficient urban layouts. The new Umayyad rulers realised that towns were essential to their policy of territorial control, especially in light of the fact that their markets played a vital role in the monetary economy of the new state.[3] These factors re-affirm the idea that 'urban culture' was not only maintained, but enhanced under the new Islamic rulers. Further, the former view that the new power neglected declining classical cities has been contradicted by archaeological evidence for the Arabs' active and planned transformation of these cities to meet new economic and commercial demands, as well as the creation of many new cities.

Many of these new cities were initially established as military encampments: the so-called *amsar* (singular *misr*), or encampment-towns, created *ex-novo*, were essential for the urban and territorial strategy. Their layout was based on various models, whatever their cultural origin. The best known examples, located in the former Roman provinces of Syria and Palestine, resembled the rectangular Roman military camp. These include Anjar in Lebanon and Aqaba in Transjordan.[4] Others copied the model of the Partho-Sassanian circular towns; this might have been the case for *amsar* in Iraq and Persia, such as Basra and Kufa, although we mainly know about these cities from literary sources. Later examples of cities built on a circular plan include the Abbasid foundations of Baghdad and Heraqlah.[5] Among the Sassanian towns that would have served as models are Ctesiphon, Hatra, Harran, Darabjerd and Firuzabad. One can even trace earlier antecedents of this pattern, always in the Mesopotamian-Persian region, such as Sinjerli (from the Hittite period), or Sagbat/Hagmatana (founded in 700 B.C. by Median kings). The plans of other cities, such as the palatine city at the Amman citadel, created on an existing town (*ex-novo*, but not *ex-nihilo*), were influenced by both Hellenistic and Central-Asian models. On the one hand, we can identify a pragmatic strategy of re-using pre-existing structures and regularising the resulting open spaces (in our case, the *souq*, or market square) by means of porticoed structures (similar to the Hellenistic models of the *agorae* of Assos and Athens). On the other hand, the pattern of segregating the Palace itself from both the palatine city (both on a hill) and the lower city populated by commoners, is reminiscent of central Asian cities.[6]

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[3] Some of the religious prescriptions of Islam reinforced the role of cities in the new state, like the need for the entire male population of a city and its surroundings to congregate for the Friday prayers. On this occasion, administrative edicts were proclaimed and read together with the religious sermon during the Khutba, or sermon (reflective of the unity between politics and religion in Islam, where praying was conducted by the Caliph or his deputy).

[4] For Anjar, see Chehab (1953), for Aqaba, see Whitcomb (1998).

A similarly pragmatic approach is noticeable in building typology. The Umayyads favoured models that could easily be adapted to different purposes, rather than spatial configurations clearly serving a single function. Buildings serving very specific purposes, such as throne halls, mosques or baths, were the exceptions. The Umayyad builders also alternated between Roman and Sassanian models in their construction of palaces and other religious and symbolic buildings. For instance, a three-aisled basilica in Mshatta ends in a Late Roman triconch hall, while at Amman and Kufa, the typical domed Sassanian throne hall can be found. This was preceded by an *iwan* opening into a courtyard. This confused alternation of extant models of symbolic protocol (and, in some cases, their co-existence) would eventually contribute to a new 'oriental' model.

The Dome of the Rock, built on top of the remains of the Jewish Temple at Jerusalem (abandoned after its destruction by Titus, and never rebuilt by the Christians, in order to fulfil the Prophecy), is extremely significant; it illustrates to what extent magnificent and symbolic buildings in key locations contributed to the spiritual and symbolic take-over of the territory. Its erection was the most important expression of Islamic political and religious ambitions; a truly propagandistic act by which the new rulers and the new religion proclaimed their link to the lineage and faith of Abraham. Moreover, it was intended as a defiant message to the Christians regarding the actual meaning of the Prophecies: its inscription reproached them for their 'polytheistic deviation' (their faith in the Holy Trinity), and embodied an invitation to conversion.[7] Something similar can be said regarding the great mosque at the new political capital, Damascus, which was built on the premises of the former Christian Cathedral. Both structures, in particular, the Dome of the Rock, are regarded as 'Late Roman' by many art historians due to the architectural typology and building techniques used, although some of the mosaic patterns display traces of Sassanian influence. It seems that the very limited use of oriental models in these buildings should be explained by their very early date of construction (during the reign of Abd el Malik), and geographical location within the former Roman provinces of Palestine and Syria. At this stage, the artisans in these provinces would have been Syrians with a classical background. The first steps towards a real merging of oriental architectural models and techniques did not take place for another decade.

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[5] Creswell (1989) figs. 137 and 171.

[6] Arce (2000).

The Mosque represents a clear example of the creation of a new kind of building, which initially portrayed two different styles, again influenced by distinct antecedents. Their adaptation was unquestionably influenced by the activities that took place within them: a mosque was mainly intended for Friday prayer, and as a meeting room for the entire male population of a town and its surroundings.

The 'Syrian' mosque was derived from the Christian basilica, its prayer hall, or *haram*, constituting a 'linear' space defined by parallel porticoes. The porticoes (in churches, there were usually two that defined three aisles along the axis of the building) were usually turned transversally, so that they were aligned with the *Quibla* wall.[8] This wall was always orientated towards Mecca, and included (from the 8th c. onwards) the *mihrab*—another alien adoption, although its Jewish or Christian origin is still debated—which the congregation faced during prayer. The number of aisles in a 'Syrian' mosque could vary from three to five, or even more. In front of the *haram*, there was a courtyard or *sahn*, possibly related to the Christian *atrium*, with a surrounding portico. Damascus is a typical large-scale illustration, while those at Al-Walid, or Hallabat in Jordan, represent more modest examples. The latter were in fact so small that they possessed no courtyard, although Hallabat possessed an external portico, which clearly drew heavily upon Christian architectural models.[9]

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[7] Grabar (1959).

[8] The layout of the porticoes in Bilad al-Sham could be related to the re-use of churches. The direction of prayer was then shifted 90 degrees: from the East, as was customary for Christians, to the South (towards Mecca) for the Muslims. When mosques, e.g., those at Cordoba, or Mértola in Portugal, were turned into churches, the opposite happened. In most cases, the *mihrab* needed to be blocked and concealed, or transformed into a secondary chapel, and a new apse introduced in the east wall: Ewert (1973). This also explains why the Cathedral of Sevilla, built on the premises of the former Congregational Mosque, lacks the directional spatial sense of a standard Gothic church.

A second type of mosque imitated the Persian *apadana*; a square hall with no clear directional orientation that was usually covered by a 'forest of columns'. In such spaces, supports were placed at regular intervals and carried lintels or arches usually in both directions. Some of these columns were sometimes eventually removed to shed more light on the inner space, creating a sort of courtyard. Unsurprisingly, almost all examples of this type are found in Persia and Mesopotamia: for instance, Kufa, Tarik Khana (Damghan), and Susa in Khuzistan. The Amman Citadel Mosque is an outstanding example of this kind of 'Persian' Mosque, found un-expectedly in Bilad al-Sham.[10]

In the subsequent stage, this distinction between 'basilica' and '*apadana*' mosques became confused and new kinds emerged that were a mixture of these types and even incorporated new features. The interesting thing about Umayyad architecture is that its influences can be clearly identified, thereby allowing the study of its transformation. In later times, these styles were again merged with other influences, so that they became more diffuse and harder to trace.

In the case of *hammams* (bath buildings), the merging of traditions is more visible in building techniques than in typology. In the Early Islamic world, the standard Roman-Byzantine plan was adapted with little change: only the *apodyterium* was replaced by a reception hall.[11] This highly standardised design may imply the presence of 'drawn' models or plans, executed in different places, with different materials and techniques, according to the resources available. For instance, the baths of Hammam As-Sarraj and Qusayr 'Amra, (both in Jordan) were almost identical in plan and elevation, but were erected using different techniques: Sarraj with finely-cut limestone ashlars of the 'Late Roman' tradition (probably due to its location very close to the quarries), and Amra with rough masonry held together by gypsum-lime mortar, a technique of Sassanian origin, which was also used at nearby Qasr Harane.

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[9] Arce (2006a).

[10] Arce (2000).

[11] See Arce (2006a).

From Merging to Hybridisation

In the next step of this process, it is possible to observe the combination of different techniques and typologies in a single building style. It might be argued that this resulted from a situation in which a conscripted workforce of artisans and technicians, from all four corners of the empire, worked on the construction of a great number of buildings in a very short period of time;[12] part of a deliberate and planned attempt to create an original and different architecture for the new state.[13]

Therefore, the true hybridisation of technical and artistic influences was inevitable. Architectural and spatial archetypes from one tradition were built with techniques, and decorated with patterns and elements from another, and vice-versa. Qasr Harane is a good example of this stylistic interaction. In this case, the typical Syrian *bayt* (a spatial unit composed of a central and elongated hall flanked on both sides by two small chambers which opened onto it) featured as the main element of the compositional plan. This was covered with diaphragm arches (common to Syrian and Parthian traditions), but built with Sassanian techniques (fig. 9), involving the use of squinches, pre-cast gypsum, structural elements and gypsum mortar. The structure is decorated with gypsum-made pre-cast niches that were composed of paired colonnettes, horse-shoe arches, and dog-teeth cornices. It is easy to understand why some scholars have regarded this amazing building as a Sassanian structure built during the occupation of A.D. 614–30.

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[12] At one point, the building 'fever' of the Umayyads actually jeopardized the finances of the state. The last Umayyad Caliph was finally obliged to give up all building activities under the weight of increasing criticism.

[13] It resembles the 'melting pot' of workers involved in the construction of the Palace of Darius at Susa where, according to its famous inscription, the Babylonians made adobe and bricks, the stonecutters from Sardis and Ionia were responsible for the stone masonry, and gold decoration was applied to the walls by workers from Egypt and Media.

The process became increasingly complex, especially where decoration was concerned. For example, the same 'Sassanian' decorative elements that were traditionally modelled, or cast, in gypsum at Harane, were carved in stone at Qastal and Amman (see below fig. 6). A further level of complexity was achieved at Khirbat Al-Mafjar (near Jericho), where stone-carved Umayyad versions of the gypsum-made 'Corinthian' capitals of the Partho-Sassanian world were found. It is remarkable that the choice was made to reproduce in stone the oriental version with its singular shape, along with details adapted to the gypsum material, instead of the original stone-carved model.

The cross-fertilisation of eastern and western techniques and typologies actually started before the Umayyad period. The disappearance of the frontier only re-activated and accelerated the natural and continuous process of exchange between neighbouring cultures. This process had gained momentum during the Hellenistic period (mainly in the Greek colonies of Mesopotamia and Persia), when this frontier had ceased to exist. Continuous cultural intercourse between the East and the West provoked the transformation of original features, sometimes with unexpected but highly original results. One of the inherited traditions involved the application of decorative features in carved stucco to a stone or brick core. This technique, apparently Mesopotamian in origin, and developed in that region during the Hellenistic period, was adopted by the Parthians, and afterwards, by the Sassanians. Although it was used extensively, and, during the Early Islamic period, was improved by artisans coming from Persia and Mesopotamia, it had already been introduced into the Levant from the East before the Umayyad era, during the Hellenistic and Nabatean periods, through the Parthian influence on Nabatean culture. The origins of this technique can be traced back to the arrival of the Greek colonialists in Persia and Mesopotamia after the conquests of Alexander. These new arrivals were confronted with an architectural tradition consisting of brick and cobble masonry, bound by gypsum mortar and lined with stucco. This forced them to adjust classical decorative and architectural features to the available material, carving or stamping them in gypsum. The resulting, hybrid decoration was adopted by the Parthians, who also introduced new Roman influences, and then eventually carried it back to the Levant—and in particular to the Nabatean Kingdom—along trade routes. Examples can be found in column shafts and capitals from various buildings at Petra—for example, Ed-Deir, Qasr el-Bint—or those from the Herodian palace at Machaerus (fig. 1).

The capitals of the congregational mosque at the Citadel of Amman (fig. 1) can, therefore, be seen as the outcome of a long process of hybridisation; the core of the column shafts and capitals consisted of carved limestone, thereby adhering to western techniques, and not the rubble masonry that was prominent in the Sassanian antecedents, or in the co-eval buildings of the Amman citadel palace itself. The decoration was executed in carved gypsum stucco of Partho-Sassanian origin, which was applied to the structural core, while the column shape and general plan of the building were also of Persian origin. The decision to use a 'Byzantine' stone-carved core in these columns resulted from the need for a more reliable support for the roof, which covered the 'forest of columns'.[14] This technique could have allowed the application of the decoration to the columns through the carving of patterns directly onto the stone itself (as was done, for instance, inside the Vestibule—see below), or into its own external façade.[15] However, in this case, it seems that the builders adopted this quicker and cheaper solution for the interior, having probably been constrained by the limited resources available. Even so, their pragmatic and utilitarian approach led them to carve decorations into the stone in areas where the adherence of the stucco could not be guaranteed, for instance, in the downward-facing lower part of the capital.

The relationship between the load-bearing structure and decoration of a building is one of the key differences between classical and Persian architecture. The close relationship and high degree of articulation between structure and decoration in Greco-Roman architecture can be explained by the 'structural' origin of its decorative elements: most features of the earliest edifices—in the first place, in temples—gradually lost their structural raison d'être and evolved into purely ornamental elements, but their display remained closely related to the original structural elements. This generated very strict syntactic rules (the Classical Orders), which prescribed the use and location of the decorative vocabulary. Thus, the Classical Orders define the use and meaning of the classical architectural language as a whole.

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[14] Arce (2002).

[15] Ibid.

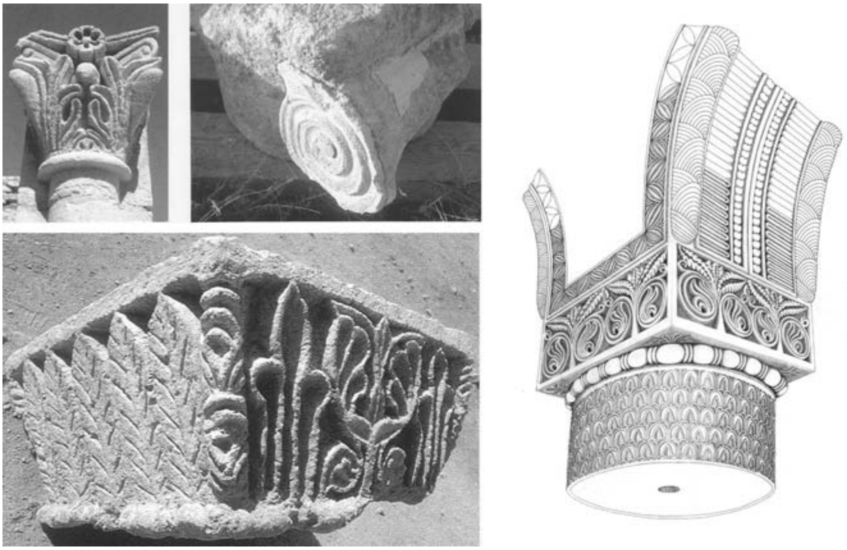

Fig. 1 Translation of shapes and techniques. a: Khirbat al-Mafjar. Bath Porch. Stone-carved 'Corinthian' capital. This capital imitates the features of the gypsum-carved Sassanian version of the classical model; b: Machaereus (Jordan). Herodian fortress. Ionic capital, with decorative features applied in stucco onto a stone core; c: Amman Citadel. Capital carved into stone imitating Sassanian models carved in stucco; d: Amman Citadel Mosque. Capital. Restoration carried out by the author based on the remains found *in situ.* The decoration in carved stucco was applied onto the stone core, except the lower part of the capital (facing down) that was carved on the stone core itself.

A classical building can, therefore, be called a 'structure' in two ways: it is both a 'construction'—from the Latin s*truere*, to build—and a "complex configuration of elements, closely inter-related by fixed rules", according to the additional modern meaning of the term in linguistics.

In contrast, in Partho-Sassanian architecture—and in Mesopotamian and Iranian architecture in general—there is a clear dichotomy between structural and decorative elements, as they were neither clearly articulated nor related from the start. Apparently, the lack of resources available in Mesopotamia led to poorly-built, load-bearing structures,[16] put together from earth, or gypsum, and stones, bricks or adobe. The decorative features faced the same technical constraints, and consisted of mud, and later, of gypsum-made plasters and renderings.[17] It was devised as a skin, coating, protecting and concealing the load-bearing structure, rather than enhancing its tectonic features. The most characteristic decoration resulted from the quick covering of extended surfaces with repetitive motifs, using stamps and moulds. This technique would give birth to the 'infinite developing patterns' that were essential in later non-figurative Islamic art.[18] Iranian architecture was also characterised by the use of timber, which was mainly brought from the mountainous and wooded areas in the north, near the Caspian Sea. The linear elements, which were characteristic of timber constructions, clearly influenced the 'forests of columns' of the *apadanas*, or the 'lintelled squinches', and may also have had an impact on the shape of some other Umayyad decorative forms of Sassanian origin, such as corbels, and coffered ceilings.

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[16] Information on Sassanian architecture and building techniques is very rare; on one hand, only a small number of ruins are preserved. This is partly due to the disappearance of the Sassanian Kingdom and the replacement of its culture by the Islamic one, and partly to the poor quality of Sassanian construction work. On the other hand,

The different relationships between structure and decoration in western and eastern building and architectural traditions, were 'subverted' and blurred by the Umayyads in their combination of materials and formal repertoires from both cultures. Apart from the examples of the decorated capitals, mentioned above, there are other outstanding examples of this intercourse, which sometimes affected the relationship between decoration and structure. For instance, in the Amman Citadel Vestibule, both concepts are apparent in the same building, even though they contributed to the same decorative feature: the Sassanian niches that are capped with horse-shoe arches, supported by paired colonnettes and decorated with dog-teeth. Here, these niches were carved into stone (not like at Harane, where they were still modelled and cast in gypsum)

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there have been few studies conducted *in situ*, and only a very small amount of material is available to foreigners, especially after the 1979 revolution.

[17] Other examples of surface wall decoration following the same 'oriental' concept, are the Sumerian mosaics with decorative pottery cones, embedded in the walls, for example, those at Warka–Frankfort (1970) figs. 8 and 9.

[18] The role of textiles must also be mentioned, in the later development and success of these decorative concepts and patterns in Islamic art. This parallel influence derives from Centro-Asiatic nomadic populations, who constructed shelters by covering wooden frames with furs and printed or woven cloths (the *yurt* of the Turkmen and Mongol tribes is the best known example). While these shelters present a clear distinction between load-bearing structures and their protective 'skin', the patterns used on these textiles for centuries influenced the applied arts and mural paintings in the region between central Asia and Mesopotamia.

in two different ways in different parts of the structure. First, they are present in the long friezes running at the base and on the top of the building and, second, cover a large surface panel in between these friezes. In the former case, the translation of this feature into stone also implies a conceptual change in its execution and display; it is no longer a decorative pattern, carved all over the surface. In contrast, in the latter case, it was carved over the wall masonry base with no regard for its joints, and was consequently closer to Sassanian styles. Instead, it is restricted and related to the elements on which it was carved: each element of the niche (the paired colonnettes, the capping arches, and the back panels) actually having been carved onto a unique ashlar, and built and interlocked into the masonry fabric. This practice adhered more closely to the 'classical tradition' (see fig. 6).

Therefore, it is clear from such instances that Umayyad architecture was a multi-coloured fusion of oriental and western components, which were in many cases hybridised without regard for their origin. We will now review in greater detail the techniques that were responsible for the structural and decorative elements which defined Umayyad architectural forms.[19]

Wall Building Techniques

Ashlar Masonry

Umayyad builders largely followed the Roman-Byzantine tradition in their use of ashlar masonry, and continued its technical development to produce outstanding results. Quarrying methods remained virtually unchanged, still involving the use of metal wedges, or plugs, feathers and broad metal chisels.[20] Stone quarries were regularly situated near to construction yards, whenever possible and, when no longer in use, would often be transformed into cisterns, ensuring a more stable water supply.

Some of the wall paintings preserved at Qusayr 'Amra (Jordan) show, among many other technical construction details, the various stages of quarrying, construction and finishing; they illustrate the pre-fabrication of ashlars at the quarry and their subsequent transportation on camels to a remote building site (fig. 2). Apart from seriously reducing the risk of damaging the cargos, the use of camels also made possible the foundation of construction sites in isolated locations, which could not be reached by oxcarts requiring paved roads. A second noteworthy point regarding the Umayyad masonry techniques represented in these paintings is that they involved the abundant use of axes, as well as chisels, in both the extraction and carving (fig. 2) processes. Axes and chisels leave permanent and identifiable cut-traces during the levelling and dressing of a stone surface.[21] The dressing and levelling of surfaces with chisels relies on the perimeter *anathyrosis* of the ashlar face, but if an axe is used, the levelling guides are provided by two series of incised axe-cuts (parallel with each other), following the direction of the two diagonals of the ashlar face. These serve as depth-control guides. After reaching the desired level on these diagonal bands, the final dressing and surface levelling of the rest of the ashlar can begin. The paintings also testify to the use of angle squares, and illustrate the final dressing of the wall surfaces in their entirety (by means of axes in the depicted case), following the construction of the building (fig. 2). Delicate protruding joints made with fine lime mortar can be found in the finest ashlar-built structures (for instance, at Mshatta and Qastal). Meanwhile, for certain structural elements bearing heavy loads, like *voussoirs* and column drums, precise and delicate joints were produced using *anathyrosis*. This consisted of a careful levelling of the perimeter band of the contact surface between stressed elements. This technique was designed to prevent the uneven distribution of stress and the appearance of cracks. It can be traced, for instance, at Mshatta.

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[19] It must be mentioned that the dating of building techniques relies on up-to-date archaeological assessments based on accurate stratigraphic analysis, carried out in recent decades.

[20] Ward-Perkins (1971), Dayyah (2001).

In the area of Syria and Palestine, limestone was mainly used, although it could be combined with basalt for heavily-loaded elements such as jambs, lintels, and thresholds. Basalt could also be used on its own, but only when there was an absence of materials that were easier to carve. The Umayyad basalt-made constructions are usually cruder, and more easily distinguishable than Late Roman buildings, which had more precise joints and more regular courses and faces.

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[21] Besides, the existence of parallel marks indicates the use of a chisel, while a more random distribution of incisions, a sort of 'fan' pattern following the movements of the cutter's arm, points to the use of an axe.

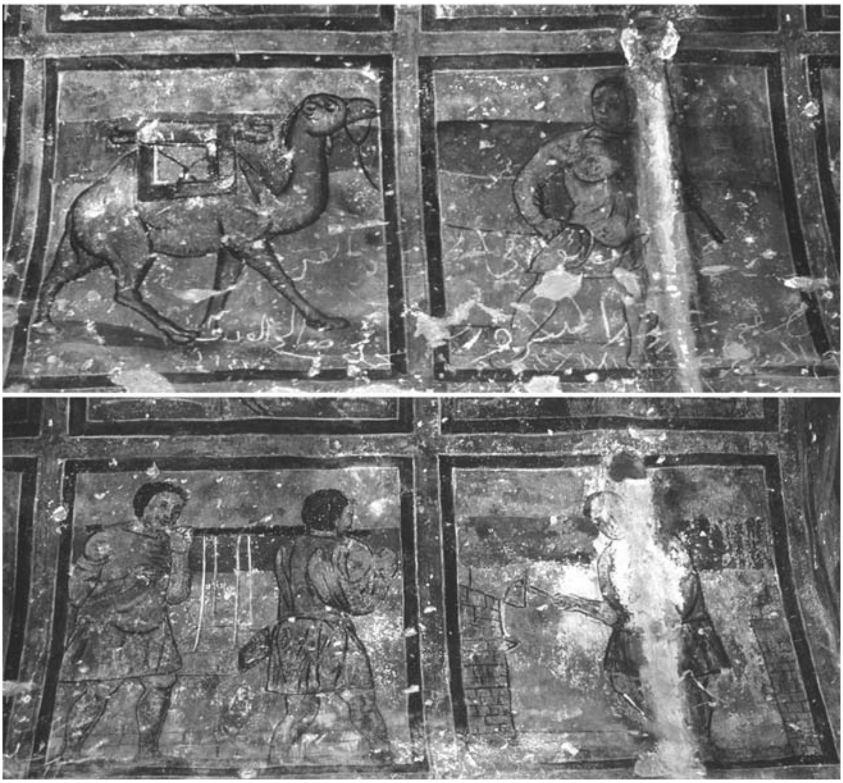

Fig. 2 Mural paintings. Qusayr ʿAmra (Jordan). a: Detail of a camel carrying stones from the quarry; b: Detail of axe carving and surface finishing *in opera*.

The technique of *emplekton*, which involved fitting together two stone faces with a filling, remained widespread. Its mechanical strength was enhanced through the use of *headers* and *stretchers* although, in most cases, only the front faces of the blocks were dressed and squared. It is noteworthy that the use of courses consisting only of headers proliferated. These courses were designed to secure walls against seismic disturbances. In other cases, headers were placed in alternating courses that followed a regular pattern. When the header did not pass through the entire girth of the wall, it was usually carved in the shape of a 'T', the *head* of which served to anchor it to the core of the wall. At the same time, the slightly divergent sides of the *foot*, which were placed perpendicularly to the face of the wall, acted as a dovetail joint that kept in place the stretcher, and were placed between two headers.

Brick Masonry

While Umayyad stone masonry derived mainly from the Roman tradition, it might be argued that Umayyad brick masonry was mainly inspired by Partho-Sassanian practice. Brick masonry (and the related pitched-brick barrel-vaults that will be described later) was the most significant Mesopotamian contribution to the building technology of the ancient world. Byzantium had, by this time, also succumbed to oriental influence, and developed high-quality brick architecture. Although the Mesopotamian tradition played a more prominent role in Umayyad architecture, variants of both Mesopotamian and Roman brickwork are still present. Roman-Byzantine techniques mainly influenced the hydraulic infrastructure—including the channels, sewers and hypocausts—and used mixed masonry with alternating courses of brick and ashlar masonry (for instance, Anjar, fig. 3). Sassanian techniques were responsible for walls and vaults that were built almost entirely out of brick and incorporated only one or two limestone foundation courses. The latter were implemented to protect superstructures from rising damp, and allowed the construction of huge span-vaults without centring, which were essential given the lack of timber. This Mesopotamian brickwork, as seen in Mshatta and Qasr Tuba, possessed thin, gypsum-based mortar joints, decorated with 'basketry' motifs and completely vertical rows of brick (fig. 3).

The bricks were quite regular in size, and square in shape. In Mshatta, we can identify two basic sizes: the bricks used for the walls are 29 × 29 cm and th. 7–9 cm, while those used in the vaults were approximately 22 × 22 × 6 cm. Circular-shaped bricks of different dimensions were used in the *pilae* supporting the *suspensurae* of the *hypocausta*. Examples can be found in several Umayyad baths (Mafjar, Hammam As-Sarraj, Ain es-Sil, Mafraq).

Adobe (i.e. sun-dried mud bricks) can also be found in Umayyad architecture, as in Qasr Mshash, where square pieces (36–37 × 36–37 × 6 cm) are used, or in the East Palace at Khan Ez-Zebib (39 × 39 × 9 cm), both in Jordan. Other buildings using adobe are found in Syria, at Jabal Says and Qasr al Hayr as-Sharqi. In this last site, two new buildings using this technique have been recently identified (adobe size: 40 × 40 × 10 cm).[22] At Qasr Harane (Jordan), mortar bricks were

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[22] Guenequand (2003).

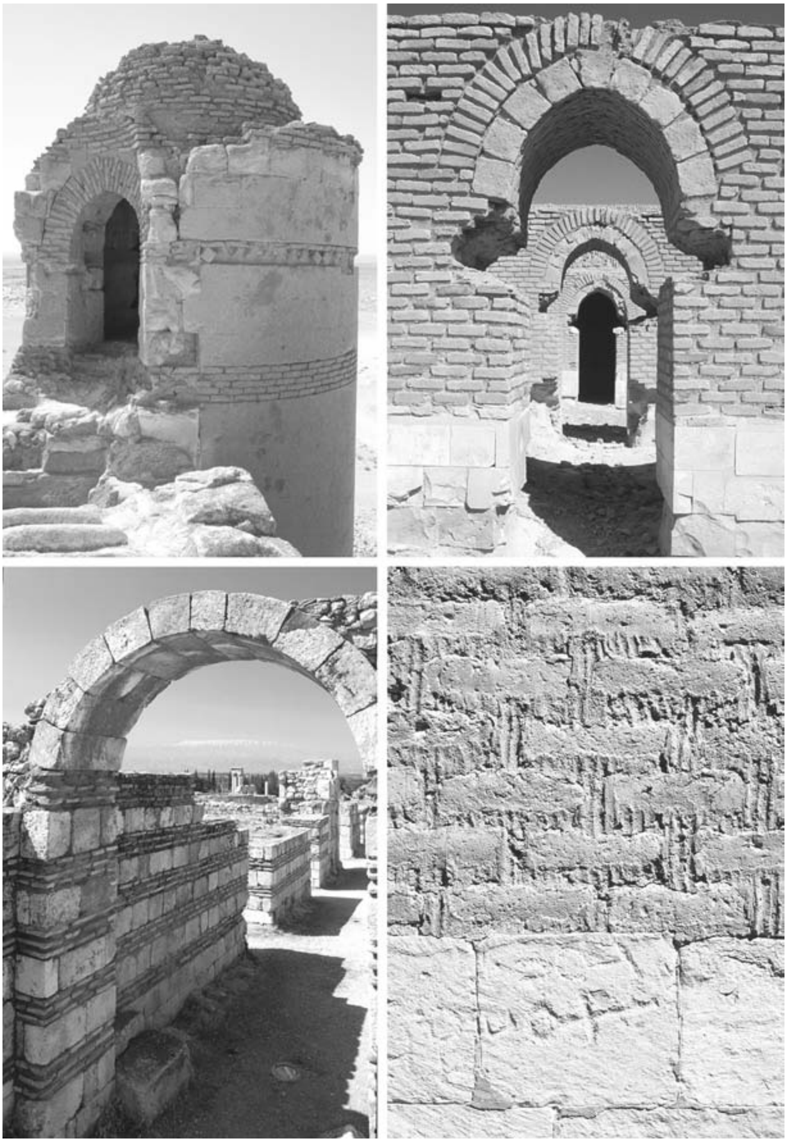

Fig. 3 Mixed Limestone and brickwork masonry. a: Qasr al-Hayr as-Sharqi; b: Qasr Tuba; c: Aanjar, 'Byzantine' Mixed stone-brickwork masonry; d: Qasr Tuba. Detail of the 'basketry' jointing in Sassanian-style brickwork (built on a stone masonry dado).

used in an unusual way; in decorative friezes and arrow-shaped, slit ventilation openings in façades.[23]

Irregular Masonry and Mixed Fabrics, Spolia and Anti-Seismic Masonry Features

Typical Umayyad rubble masonry walls were composed of irregular, medium-sized, un-squared blocks, held together with lime mortar, mixed with ashes, and joined with fine chipping. They were subsequently plastered with at least two layers of lime-rendering. Herringbone incisions were made on the first of these, which were intended to serve as a grip key for the second.[24] Numerous late antique antecedents of this technique exist in the region. In addition, Umayyad walls consisted of horizontal 'layers', h. 40 to 80–100 cm, depending on the construction quality and importance of the building.[25] Each layer could be composed of one, or several, courses of boulders, of which only the final upper face was levelled horizontally, and covered with a thin layer of lime mortar. This technique should not be confused with the Sassanian practice, to be described below, which made use of boulders and gypsum-based mortar.

Some examples of this Sassanian masonry technique can be traced in Umayyad structures, such as Qasr Harane, where it was used extensively throughout the building, or Amman Citadel, where it was restricted to the columns, arches, staircase vaults, and lintels (it is found combined in walls built with the 'standard' lime-based mortar technique, described above). It would appear that boulders were embedded in a gypsum-based mortar, and defined regular layers, or 'courses'. Although these layers may vary in height from 58 to 72 cm, each was kept level overall. The same mortar as that used in the core of the wall was levelled, and employed as a final facing (rendering) of the lateral and upper faces of each 'layer', which were executed simultaneously. A new 'course', or layer, was built on top of this levelled surface, giving it an appearance similar to that of *pisé* or *tapial* walls (rammed earthen walls, built with the help of wooden formwork). This would lead to the hypothesis that these walls were built with the help of a formwork. However, the absence of vertical joints in each of their 'courses' would contradict this theory, considering that it is impossible to build a continuous formwork running along the entire length of a wall. The use of a quick-setting, gypsum-based mortar that gradually stiffened as work proceeded, made possible the construction of this unique masonry without interruption, and even facilitated the 'decoration' of its surface with finger markings ('basketry' and 'wavy' patterns were used) before its final setting. Mixed fabrics, such as the alternating limestone and brick courses at Anjar (fig. 3), were nearly always Roman-Byzantine in origin (a sample from Ghassanid Hallabat had alternating courses of basalt and limestone corresponding to the courses of headers and stretchers).

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[23] Urice (1987). The decorative patterns associated with these bricks are of Centro-Asiatic origin.

[24] Alternatively, patches of tiny, crushed gravel pressed on the drying surface of the first layer, can be found as grip keys between layers of plaster (e.g. at Umm al-Walid or Qasr Hallabat, in Jordan).

[25] These are the respective heights found at the congregational mosque and the dwellings at the Amman citadel.

Other walls possessed finely-dressed ashlars on their exterior, and rubble masonry on their interior. The walls of the *iwan* that preceded the throne hall of the citadel at Amman provide one example. The optimisation of resources seems to have been the general aim: expensive finishing was only applied where necessary, although an appropriate display of luxury was, nonetheless, always present. Naturally, such pragmatic building practices employed large quantities of *spolia* (mainly lintels, columns, capitals, and marble slabs).

One must also note the continuity and further development of anti-seismic features, which were no luxury in this earthquake-devastated region.[26] These included wooden tie-beams, used in porticoes and inserted in walls, arched lintels with joggled-joints to prevent the lowering of the *voussoirs*, stone-carved *chains* in towers (including a complete course of inter-locked, basalt and ashlar masonry fabric), lead sheets placed in the joints of column bases, and the improved system of headers and stretchers, mentioned earlier.

Mortars and Lime Production

The mortars applied by the Umayyads clearly demonstrate the merging of two different traditions: they used both the western lime-based mortars and eastern, gypsum-based mortars. These were applied according to their specific characteristics, sometimes even within the same building, or the same wall. At the citadel of Amman, for instance, most of the masonry consists of lime mortar, while the door lintels and pillar shafts consisted of boulders and were constructed from gypsum mortar. Gypsum-based mortar has a quicker setting time, which means that these elements could have been constructed using simple supports that could be removed after a few hours, or even minutes.

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[26] For a complete review of these features, see Arce (1996a).

At the same time, the shortage of wood in the Syro-Palestinian region meant that the Umayyads could not waste timber by using it as fuel, and forced them to optimise the production of lime. Instead of the traditional 'high-flame' lime-kiln (a 'cooking' vault situated above a firing chamber, which required a constant fuel supply), 'low-flame' kilns were dug out, consisting of single spaces with just a few air holes at their base. In these sunken, conical chambers, limestone layers alternated with long-lasting, high-heat-producing fuels, such as olive pits, nut shells and pine cones. As no additional fuel needed to be added during the firing, this process was much more economic, and the combustion more efficient.[27] At what point this type of kiln was initially developed is not yet clear. Whatever the case, the discovery of Umayyad lime kilns at Jerash and in the citadel of Amman, proves that the 'low flame combustion' concept is not a modern invention, but much older in date.

Structural Roofing Elements

The hybridisation discussed thus far was probably most striking in the case of roofing structures. Umayyad arches, vaults and domes contributed to new structural and building concepts and led to a new era in the history of construction.[28]

Diaphragm Arches, Ribbed Cross 'Ceilings' and Vaults

A diaphragm arch is a self-standing arch that is placed transversally in a room, in order to reduce the span of its ceiling. The resulting sections can be covered by a lintelled ceiling made of wooden or stone beams, trusses or, alternatively, barrel vaults resting on the arch and the perimeter walls. It is said that this roofing system was devised by the Parthians—the oldest examples come from Ashur, and the palaces of Taq-i-iwan (Khark) and Hatra (fig. 4)—and later adopted by the Sassanians. It is possible that an early Parthian influence led to the widespread use of diaphragm arches with lintelled ceilings during the Nabatean and Classical periods in the Levant (Syria & Palestine) and, in particular, in the Hawran region (Southern Syria). Conversely, it seems likely that the Umayyads imported the technique of resting transversal barrel vaults on diaphragm arches to the Levant from Iran. This is suggested by the fact that no earlier examples of this variation exist in the region, and it was already present in the earliest Parthian examples: at Ashur (fig. 4) and Khark.

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[27] Arce (2003a).

[28] For an in-depth study of these systems, see Arce (2006 in press).

Arches could be multiplied and placed in parallel rows, defining regular subspaces or bays, each of them covered independently. This technique was implemented in the prayer halls at Damascus, Cordoba and elsewhere. The arches were also systematically used in residential dwellings, especially as cistern covers, when their span exceeded 5 m.

A further development was the use of pairs of arches. These were used to create the first cross-ribbed ceilings, by being crossed perpendicularly and placed across the span of square rooms. The earliest-dated application of this innovative system was discovered at Qasr Harane, and has been dated to the first decades of the 8th c. (fig. 4). Later, as in the mosques of Cordoba and Bab el-Mardún at Toledo (9th–10th c.), the intersecting arches were duplicated, so that ceilings were divided into 9 square, or oblong, sections. The most sophisticated application of this technique entailed the 'fractal' repetition of a secondary series of inter-laced arches, covering the square sections defined by the first series (fig. 4). These pairs of arches could be rotated diagonally to the walls. Various combinations of this technique became increasingly sophisticated: 8 arches, arranged into 4 pairs (2 parallel, and 2 rotated diagonally to the walls), were used to define an 8-pointed star. The remaining sections of the ceilings at Cordoba and Toledo were not covered by lintelled coffers, as in the earlier examples from Harane, but by vaults, so producing the first ribbed vaults. This concept would be reproduced much later, both in the mausoleum of the Sultan Sanjar at Merv, and in Gothic architecture.[29]

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[29] For an in-depth review of these issues, see Arce (2003a).

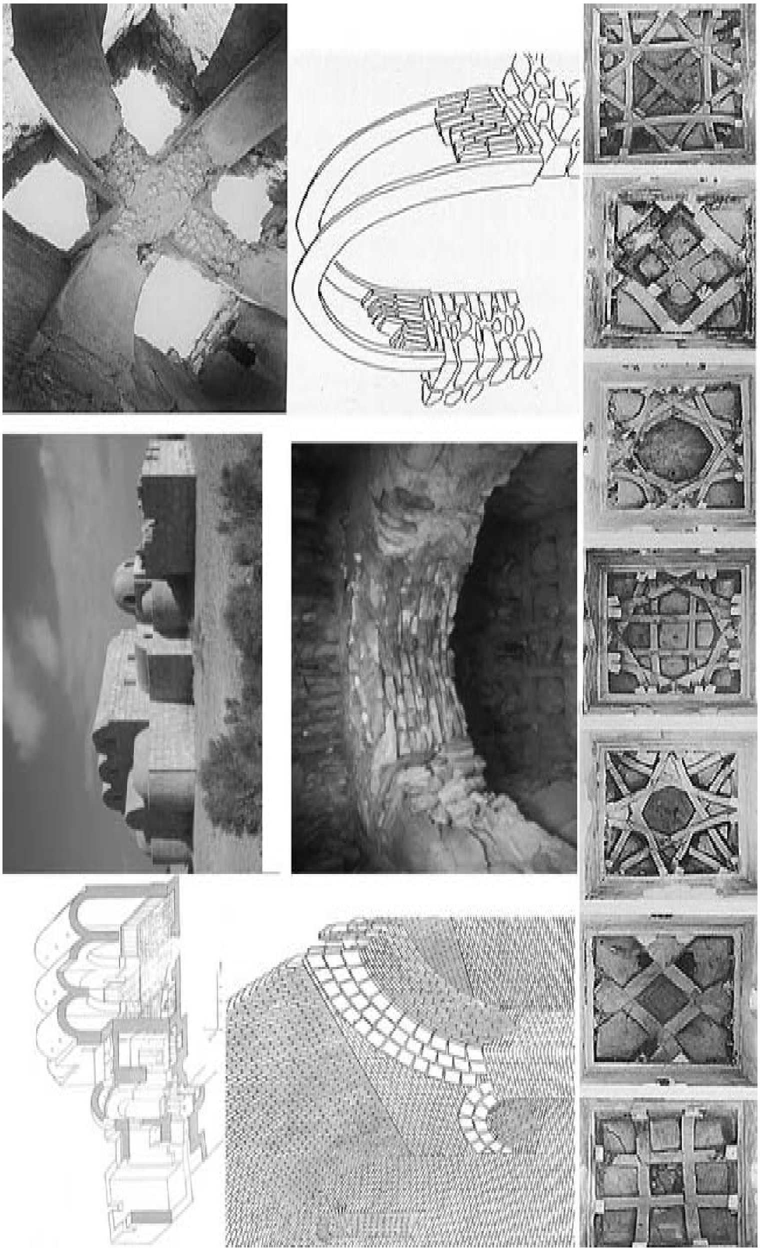

Fig. 4 Diaphragm arches and cross-ribbed vaulting. A&b: Qusayr ‘Amra. Vaults on diaphragm arches; c&e: Harane arches with embedded ribs & first cross-ribbed ceiling; d: Ashur. Parthian palace. Pitched-brick barrel-vaults on diaphragm arches (From Reuther 1939); f: Ukhaidir arch with embedded cast gypsum ribs; g-m: Bab al-Mardún Mosque (Toledo). Cross-ribbed vaults.

Poly-lobed, Pointed and 'Horseshoe' Arches. Reduced-span Centrings

The poly-lobed arch is a singular and very characteristic element of Islamic architecture. It has been questioned whether 'Spanish' Umayyad builders "transformed oriental decorative shapes into forms of construction, when in most instances, the evolution runs in the opposite direction".[30] The assertion of Ettinghausen and Grabar is based on their belief that this element initially appeared in the mosques of Al Andalus (Cordoba and Bab al-Mardún) when, in fact, the first examples are found in the Early Umayyad mosque at Hallabat in Transjordan.[31] At Hallabat, these first poly-lobed arches were situated in the relieving arches above the doors. It is interesting to note that in this tiny mosque, the Umayyad builders experimented with two types of lobe: hollow/concave; and protruding/convex (fig. 5). In the first case—which

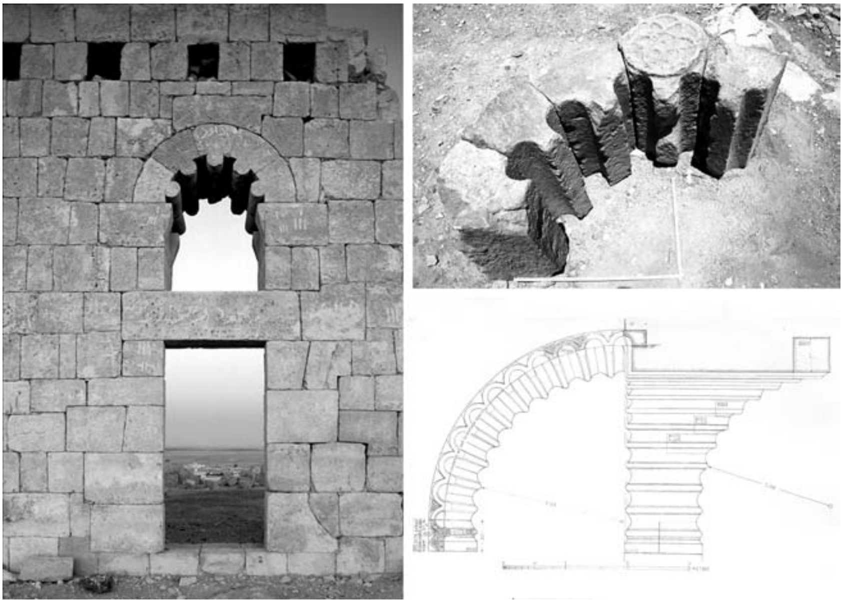

Fig. 5 Poly-lobed arches. a: Hallabat mosque. Protruding convex lobes; concave lobes; c: Khirbat Mafjar. Polylobed arch and groin vault.

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[30] Ettinghausen and Grabar (1994) 137.

[31] Similar to the case of the first ribbed vaults from these same mosques, described earlier, that also have an earlier antecedent in Bilad al-Sham, at Qasr Harane.

would become prevalent—the lobe was carved away so that it corresponded with the joint between two *voussoirs*, while in the second, each protruding lobe was fully carved into the interior of every single *voussoir*. Both are clever and clear translations of a decorative feature into a structural element.

The pointed arch, used in both arches and vaults, is an equally distinctive feature of Early Islamic architecture. It has been suggested that the arch of the Justinianic church of Qasr ibn-Wardan was its earliest antecedent. However, this arch seems instead to have been the result of inadequate centring, or other construction difficulties. The first true pointed arches were built during the Umayyad period. The offset centres of these arches could vary from one-tenth of the span (at Amman, Qasr Tuba and Mshatta, fig. 6), to one-seventh or one-eighth (at Khirbat al Mafjar).

The origin of the horseshoe arch is rather controversial, since it was developed almost simultaneously in different areas; Umayyad architecture seems to have drawn on both Sassanian horseshoe arches on decorative plaster, or stone friezes (Harane, Amman, Qastal), and stone-masonry arches from the Byzantine world (Mafjar and Amman). Antecedents of the latter can be traced in Byzantine Syrian churches, like that of Bizzos (6th c.).

The actual arch of many masonry-built arches began at a higher level than their formal springing line, since the construction of the first *voussoirs*, in many cases horizontally-projecting courses, did not require the support of centring devices. In this way, the actual span that had to be crossed with centring was reduced to as little as two-thirds of the original. In many cases, this was combined with *voussoirs* projecting inwards and outwards (i.e. towards the interior and exterior of the arch), which offered support to span-reduced centrings as, for example, in the vestibule of the citadel at Amman (fig. 6). The inward projection was usually carved away afterwards.[32] This procedure had been widespread since the Roman period and several antecedents can be found, for instance, in the Roman temple at Atil in the Hawran (2nd c. A.D.), or in the baths at Philippopolis (3rd c.).[33]

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[32] For a complete review of these features, see Arce (2003a).

[33] Arce (2003a).

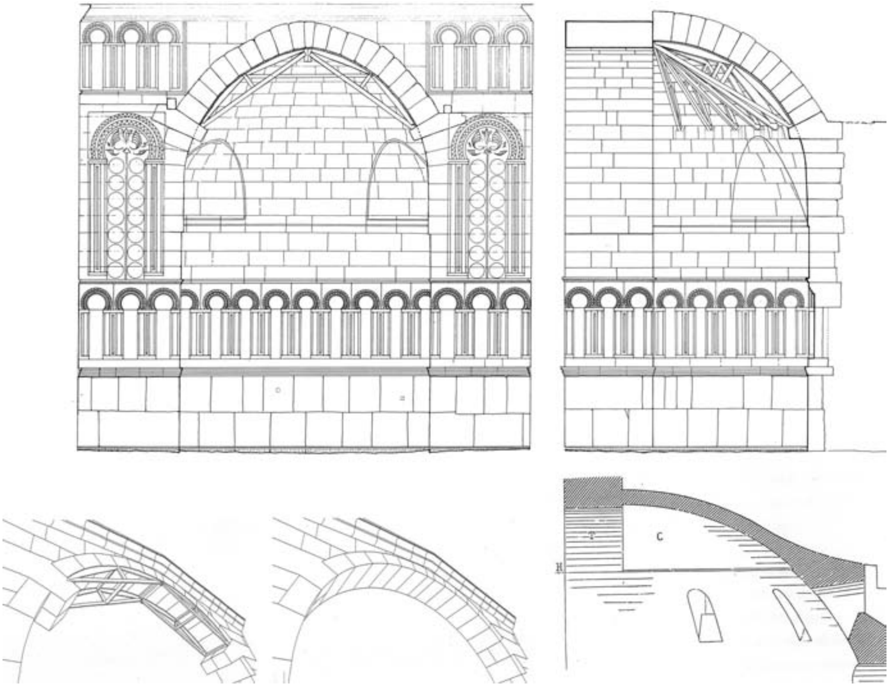

Fig. 6 Pointed arches and reduced-span centrings a&b: Amman Citadel Vestibule. Elevation and section of the lateral arches and corresponding semi-domes. Notice the span-reduced wooden centring used in the construction of a pointed arch and the projecting voussoirs on which the centring rests. Notice also the parabolic 'fake' squinches that allow the transition between the square plan and the the semi-dome that they support: the squinches are not 'built' with voussoirs or individual elements, but 'sculpted' on the series of projecting horizontal courses of stone masonry, the rest of the semi-dome being 'built' with spheric domical voussoirs prefabricated according to the Roman-Byzantine system. Notice as well the Sassanian-origin decorative feature of the niches with horse-shoe arches used, on the one hand, on the upper and lower friezes (where each element is carved on a sole and single stone block interlocked in the ashlar masonry); and on the other one, in the intermediate large panels (where the decorative feature is carved all over a section of masonry wall with disregard for the location of the joints); c&d: Atil (S. Syria) Roman Temple. Reconstruction of the reduced span centring resting on projecting voussoirs system used in the construction of the diaphragm arch; e: Constantinople *Hagia Sophia*. Detail of the semidome resting on the thick arches that support the central dome (Choisy).

Vaults

1. Brick Barrel-Vaults Built Without Centring (or 'Pitched-Brick Vaults')

As mentioned above, brick masonry and its most relevant structural achievement, the barrel-vault without centring, were the most significant Mesopotamian contributions to ancient building technology (the oldest brick vault of this kind, found at Tell al-Rimah in northern Iraq, is dated *ca.* 2100 B.C.!).[34] They had already been adapted in Egyptian structures from the New Kingdom, such as the Ramesseum granaries. These vaults consisted of rings of vertically-laid bricks, which lent slightly to one side. The first bricks were placed against the end wall of the room to be roofed, and rested against rings that had been laid previously (fig. 7). The unusual vertical arrangement of the bricks was held together with quick-setting gypsum mortar. It thus became possible to cover rooms with a large span very quickly. The span could be reduced by using over-hanging horizontal layers of brick, which followed the vault profile, and even by using an offset, marking the false springing-line of the vault. This solution was initially reached in Sassanian Ctesiphon. It was later adopted in the vaults of the unfinished palaces of Mshatta and Qasr Tuba (fig. 7).

The laying of bricks on their edges is one of the strangest, but most characteristic features of ancient Mesopotamian and, in particular, Parthian architecture (see above fig. 4). The deployment of this unusual method, which was passed on to the Sassanians and the Umayyads, can be easily explained in the cases of arches and vaults (due to the use of a building technique that did not involve centring). However, it is harder to understand why it was employed in walls or pillars,[35] given that it did not contribute to their stability and could only be constructed with fast-setting gypsum mortar.[36] The intersection of two barrel vaults built with this technique resulted in a peculiar 'cloister vault', often

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[34] Oates (1996) fig. 28.

[35] Examples can be found in the Parthian palace in Ashur: Reuther (1939b) fig. 99a and b and 100.

[36] A possible explanation could be related to the fact that baked bricks have less porosity and less water absorption capacity than the mortar employed. Consequently, this lay-out of the brick could eventually reduce the rising damp that was a major threat to brick structures in Mesopotamia. This solution was the result of a trial and error empirical process. Alternatively, it could have been a mere transposition to vertical elements of the method used in vaults.

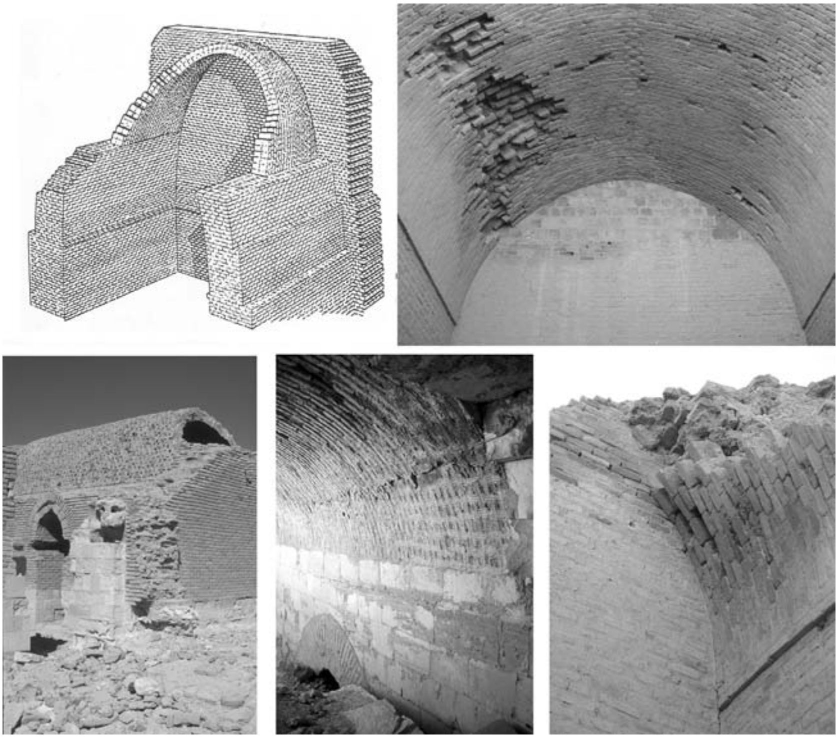

Fig. 7 Sassanian pitched-brick vaults built without centring a: Sassanian model (From Reuther (1939)); b&d: Mshatta; c: Qasr Tuba; e: Qasr al-Hayr as-Sharqi.

found in Khorassan. Herrmann has labelled this, a ‘Quadripartite lanceolated vault’.[37]

2. Squinch Vaults

This was a very peculiar type of vault, which was once again based on Sassanian antecedents,[38] and was based on the same structural and technical concepts as the pitched-brick vaults. The construction of a squinch vault started with the placement of a small arched course in each corner of a square room. It proceeded with the addition of new and increasingly large arches, leaning one on top of the other, thereby defining four corner half-cones that met in the centre of each side of the room (fig. 8). The remaining square opening could then be covered by repeating the process, as is still the practice in the houses of the Khorassan region (north-western Iran), or by re-starting the process from the newly-created corners.[39]

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[37] See Herrmann (1999).

[38] Also known as *khorassani*, due to the geographical area where it is commonly found.

Squinch vaults were apparently hardly ever used in Early Islamic monumental structures, judging by the lack of surviving examples from the period. The only surviving vaults are much later: in the East, there are the Khorassan houses and the congregational mosque in Isfahan (where the vaults date from the 10th c.); in the West, there is the vault of the 'Cuba' (from the Arabic, *Qubba*, or dome), also known as the

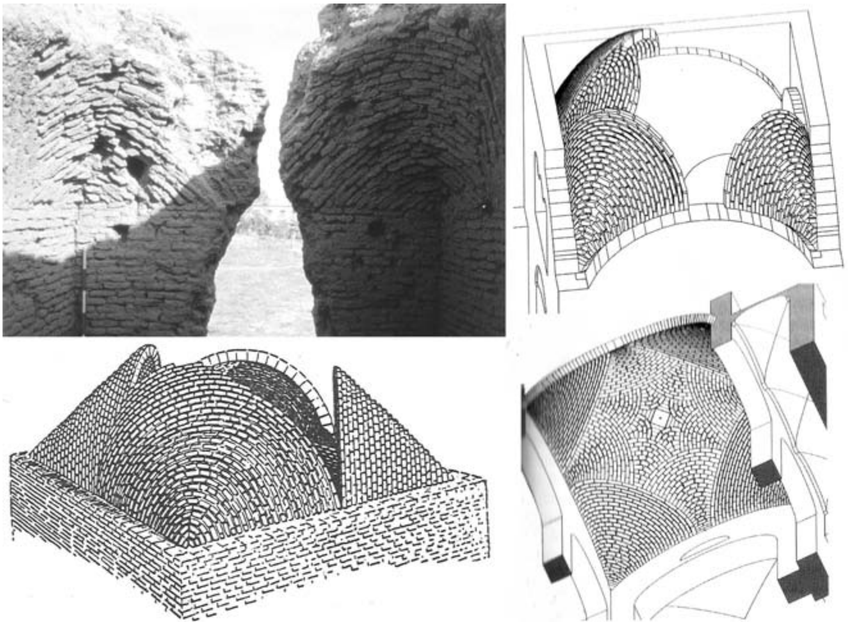

Fig. 8 Squinch vaults. a: 'Khorassani' vault at Merv; b: Sassanian Squinch vault (From Reuther (1939)); c&d: Cuba di S. Domenico. Castiglione, Sicilia. (From Copani, P & Buonanno, L. 2003).

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[39] Reuther (1939b) fig. 130.

San Domenico 'church', or 'mill' (fig. 8), near Castiglione in Sicily, that is tentatively dated to between the 11th and the 12th c.[40]

3. 'Byzantine' Mixed Brick and Stone Masonry Vaults

Brick vaults of the Byzantine tradition can be identified in several Umayyad buildings. The first courses of *voussoirs* in the majority of these vaults—which proceeded from the springers and did not require a centring to be laid—were cut in limestone. The rest of these vaults were executed in brickwork. In Khirbat al Mafjar, there are examples of barrel and cross (or groined) vaults, and a dome on pendentives, which was constructed from this mixed brick-stone masonry.[41] Vaults have been found which comprise a mixture of techniques; put together with stone slabs, or even light concrete (using volcanic tuff), instead of brick, and displaying a great variety of building solutions.[42] Nevertheless, it must be stressed again that the technical hybridisation of Roman and oriental techniques had already started in the late antique period, for instance, in the un-centred and pitched-brick vaults constructed by Byzantine masons. Indeed, Byzantine masons had perfected the use of transversal arches to sub-divide large areas into small sections, which were filled up using an improved version of the old Mesopotamian method. [43] Examples of this practice are evident in the Byzantine cistern at the Aleppo citadel, or at Qasr ibn-Wardan (both in Syria). However, it is curious that modifications of the Byzantine pitched-brick vaults with thick mortar joints and inclined rows of bricks were never applied by the Umayyads, who preferred the original 'Sassanian' technique.[44]

Domes, Squinches and Pendentives

The Umayyad fusion of two cultural models is also apparent in their structural systems, particularly in their use of both squinches (originally an Iranian invention) and pendentives (the most outstanding achievement of Syro-Byzantine masons) to support domes. This fusion fundamentally influenced their construction of domes. These were made in various shapes—for example, hemispheric or 'umbrella'-shaped—and could be executed in a range of materials, such as limestone, shale,[45] volcanic tuff[46] or, as in the Dome of the Rock, timber.

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[40] Copani & Buonanno (2003).
[41] Hamilton (1959) figs. 36–41.
[42] Arce (2006) in press.
[43] Choisy (1883).
[44] See above and in Arce (2006) in press.

1. Domes on Squinches

The Sassanian domes on squinches can be seen as a particular type of the squinch vault described above. The half-cones in each of the 4 corners of these domes did not reach as far as the middle of the room. Instead, some space was left between them that was filled with horizontal courses. These resulted in a horizontal circle at the crown of the squinch arches, on which the domes would rest. Such domes had a half-elliptical section, and were built with horizontal circular courses, made of gypsum mortar and without centring (fig. 9). In the dome erected over squinches in the Sassanian palace at Sarvistan (Iran), the transition section, formed by the drum with the squinches, was made of cobbles and roughly-cut stones embedded in gypsum mortar (as were most of the building's walls), while the dome itself was built with bricks. Meanwhile, in the dome over squinches at the Firuzabad Palace (Ardashir's Palace, 3rd c.), both the squinches and the dome were built with cobbles embedded in gypsum mortar.[47]

At Qasr Harane (an Early Umayyad structure dating to the first decades of the 7th c.), different examples of these squinches can be seen (fig. 9). They feature shapes and techniques from the Sassanian tradition. The 'Reception Hall' at the Amman Citadel featured a Sassanian dome on parabolic-conoidal squinches (figs. 6 & 9), which was built in stone with the means and know-how of local stone-cutters of the Byzantine tradition. It is an extraordinary example of the unexpected results obtained from this merging of techniques and shapes in the first half of the 8th c. The translation into stone of shapes with no possible stereometric solution posed a real challenge to the experienced stonecutters responsible. They rose to the task cunningly by carving or, rather, sculpting the shape of these squinches out of a series of overhanging and horizontal stone courses. These horizontal courses

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[45] For example, the one which had disappeared at Hammam as Sarraj.

[46] For example, at Hallabat.

[47] Reuther (1939). This building technique, and in general, Sassanian architecture, could be described as an architecture of 'plaster-masons' (see figs. 5, 18 & 19), while the Syrian-Byzantine tradition was an architecture mainly produced by 'stonecutter-masons' (see figs. 13 & 30); terms coined and often used by Tiziano Mannoni, who distinguishes between *muri da muratori* and *muri da scalpellino*, i.e. plaster masonry vs. stone-cutting masonry.

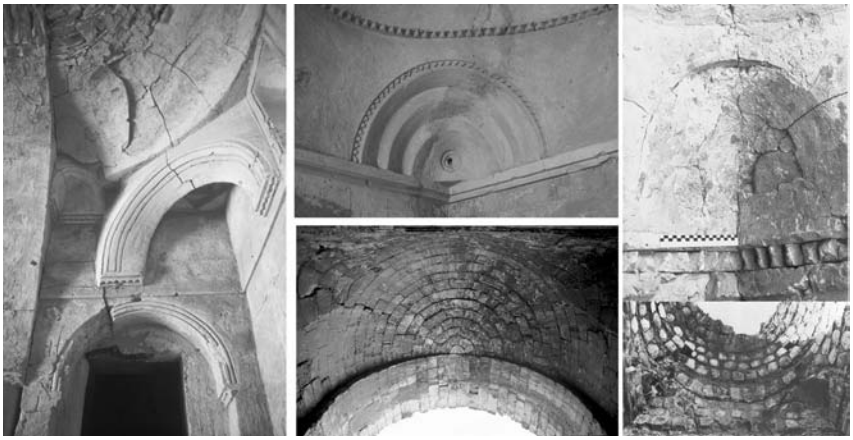

Fig. 9 Squinches. a&b: Harane (three different kind of squinches); c: Amman Citadel Vestibule. 'fake' squinches (Note the different building technique used in the lower and the upper section of the structure) d&e: Sarvistan (Iran).

reached the level of the crown of the squinches, which corresponded to the semi-circumference on which the parallel semi-dome rested. From that level, the stone-cutters constructed the semi-dome according to the 'standard' Byzantine method of building stone domes; with the use of spherical and radial joints.

A unique case of lintelled squinches supporting a dome is displayed in the Amman citadel throne hall. This *unicum* is another example of the translation into stone of a Partho-Sassanian shape, in this case originally conceived in timber. Antecedents of this element can be traced in the Parthian Palace at Nisa. This is unsurprising, given that it had been a standard roofing system in northern Iran and neighbouring regions, such as Azerbaijan, Georgia, Armenia and Tajikistan.[48] To a certain extent, it followed the principle of the squinch vault, although, instead of arches, it included horizontal beams that were placed diagonally. These defined a series of squares, which were inscribed within one another and rotated 45 degrees (fig. 10).

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[48] For a complete review of these features, discovered during the excavation and restoration project, see Arce (2000): "Un tipo inédito de trompas en la arquitectura omeya".

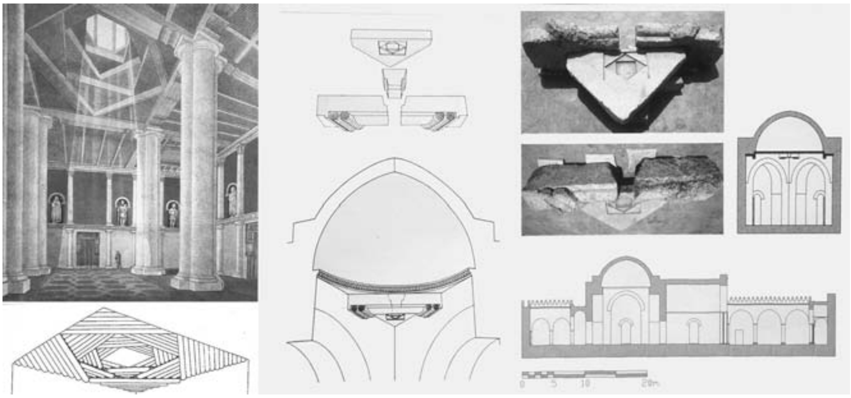

Fig. 10 Dome on 'lintelled squinches', from Amman Citadel Throne Hall. c-h: Reconstruction by the Author based on material evidences found *in situ*. Antecedents in timber from, a: Nisa. Parthian Palace (Pugachenkova); b: Caucasus region (Azerbaijan, Georgia & Tajikistan).

2. Domes on Pendentives

The following examples of domes on pendentive illustrate that the high levels of excellence reached by Syro-Byzantine stone-cutters were developed and improved during the Umayyad period, and that classical stereotomy reached its apogee in Umayyad buildings. In fact, pendentives might be viewed as the most important achievement of late antique stone-carved masonry.

First of all, the pendentives from the bath hall of Mafjar merit discussion.[49] 'Normal' pendentives are basically the shape of a hemisphere, and are intersected by 4 planes that rise vertically from the sides of the square to be covered (inscribed in the circumference base of the sphere). In this way, they create vertical, semi-circular arches in the lateral cut sides of the hemisphere. The modified pendentives from Mafjar are an extraordinary geometrical *tour de force*. Their basic figure is smaller than a hemisphere, while their 4 intersecting planes constitute the sides of a pyramid. Thus, the resulting arches are parabolic in shape, and are in an inclined, rather than vertical, plane. This means that the builders must have added sections of barrel vaults to reach the semi-circular sides of the room.

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[49] Hamilton (1959) 81 and fig. 42.

Further examples include the *exedrae* at Mafjar and Hammam As-Sarraj. These both possessed semi-domes that had been built in courses that radiated centrally from their rear.[50] At Mafjar, the stone-cutters displayed their expertise in a rather eccentric manner: they suspended a chain of cut stone from the apex of the semi-dome. It ended in a sort of tear-like pendant (fig. 11). All of the pieces of this feature (including the inter-locking links of the chain) were carved from a single piece of limestone.[51]

The fragments of a dome on pendentives, recently retrieved from the mosque at Hallabat, constitute our final example of this technique.[52]

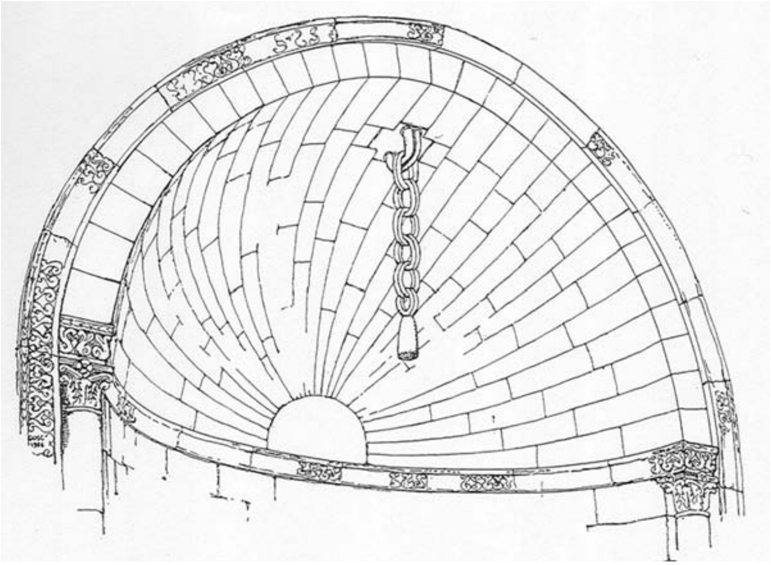

Fig. 11 Semi-dome & niche built in courses radiating from the back: Khirbat al-Mafjar.

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[50] Hamilton (1959) figs. 49a and b.

[51] "The cross-shaped piece at the top from which the whole 'chain' hangs is a true domical voussoir; in the construction it must have been kept to the last, cut ready with its chain, and finally dropped into place to close the structure." Hamilton (1959) 91.

[52] A feature discovered by the author during the ongoing excavation and restoration project carried out at the site, not yet published.

The remains of this dome testify to a more formal constraint and technical proficiency. Whereas the spherical triangles, or pendentives, were normally separated from and constructed after the 4 supporting lateral arches, in Hallabat, the *voussoirs* of the arches, and the neighbouring sections of the pendentives, were carved from the same block. These features make this dome a technical antecedent of those dating from the Spanish and French Late Renaissance, the period in which stereotomy—and geometry in general—is supposed to have reached its climax.

Pre-cast Gypsum Structural Elements

Pre-cast gypsum structural elements are purely Sassanian in origin. They include ribs functioning as formwork, or temporary centring in the construction of arches (fig. 12),[53] and the capital-plaques from which the ribs spring, are purely Sassanian in origin. They can be found in important Umayyad buildings, like the Amman citadel and Qasr Harane.[54]

Surface Decoration:
Mosaics, Mural Painting and Carved Stucco

Decorative Patterns and Concepts: Surface vs. Structure

The principles behind the relationship between structure and decoration in the eastern and western traditions, which were discussed earlier, can also help us to better understand the specific characteristics of Umayyad decorative techniques. Here again, the same two main characteristics can be clearly distinguished: mosaics and mural paintings from the classical world; and oriental gypsum-plaster stucco.

1. Mosaics

In Late Antiquity, Bilad al-Sham had a long-lasting tradition of mosaic production, especially during the 5th and 6th centuries.[55] The tradition

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[53] Arce (2003a).

[54] Arce (2001a).

[55] During this period (7th–8th c. A.D.), this technique disappeared from the rest of the Mediterranean. Meanwhile, it blossomed in the Islamic Levant.

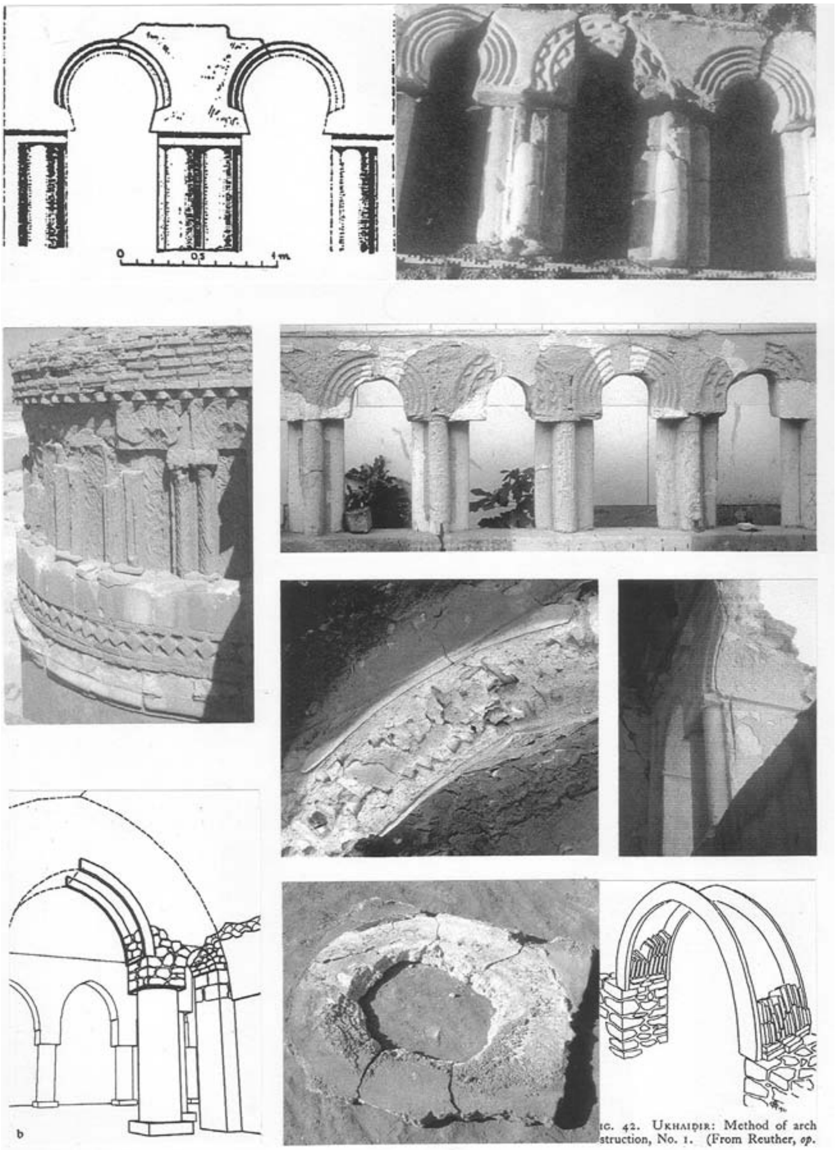
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Fig. 12 Gypsum pre-cast structural elements. Niches, ribs and 'capital-plaques'. a: Sassanian niches from Ctesiphon; Umayyad niches: Jabal Says (b&d) and Qasr al Hayr as-Sharqi (c); Embedded ribs and 'capital-plaques': Harane (e); Amman Citadel (f&g) and Ukhaidir (i).

was revived in the Umayyad Period after the hiatus of the Sassanian invasion. It was adopted by the new rulers to decorate the luxury pavements that were designed as status symbols.[56] These pavements were used extensively, not only on floors, but also on walls and domes. Examples include the parietal mosaics on the drum of the Dome of the Rock, those on the barrel-vaults of the entrance canopies of the same building, and the traces found on the 'dome on pendentives' at Qusayr 'Amra. Mosaics were one of the few decorative techniques used by the Umayyads in which no Partho-Sassanian influence can be identified. Indeed, even the decorative patterns they used are predominantly Byzantine.[57] However, it would appear that the Umayyads increasingly favoured purely geometric patterns which accorded with the Islamic prohibition of figurative representation.[58]

From the Hellenistic period onwards, the design and execution of mosaics improved considerably. The transition from the bi-chromatic mosaics of the Hellenistic period, to the Byzantine and Umayyad mosaics, which incorporated glass *tesserae* and gold leaf, was accompanied by the evolution and improvement of mosaic beds.[59]

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[56] This tradition would also be kept alive by Christian communities until the 9th c. A.D. This was possible because, although the covenant of the Caliph Omar prohibited the construction of new churches, it still allowed the refurbishment and re-decoration of existing ones.

[57] Only a few features of Sassanian origin can be recognised at the Dome of the Rock.

[58] Especially after the iconophobe decree of Caliph Yazid, which ordered the removal of the majority of the mosaics of the churches of Bilad Al Sham. Remarkably, the promulgation repeated the iconoclastic revolution of the Byzantines, a century earlier.

[59] "The small black and white limestone and black *tesserae* of the mosaic floor in the *apodyterium* of the Herodian fortress of Machaerus, dated to the 1st c. B.C., were laid upon a layer of lime a few millimetres deep which, in turn, had been laid on a shallow bed of stone chips embedded in a mortar of lime mixed with ashes. In the vestibule and side rooms of the earliest church dedicated to Moses on Mount Nebo, dated to the late 4th c. to early 5th c. A.D. dull white cubes, larger than those used in the polychrome pavements of the sanctuary, were set in a layer of mortar directly on the bedrock…The mosaicist who created the polychrome compositions of the 2nd half of the 4th c. A.D. commonly used a bed composed of different layers. The soil was settled with a compact layer of local red earth (*terra rossa*). On top of this was a layer of small round pebbles placed close to each other and covered by a layer of lime with ashes mortar. This smooth bed covered the whole area to be decorated to a thickness not exceeding 15 cm, and on it was spread a layer of wet lime plaster (usually not more than 1 cm thick). This was done in stages according to the area the mosaicist could work on before the plaster became dry. Normally the mosaicist would draw the outlines of the composition in red; then he would start laying the *tesserae*. These were cubes of 1 cm, cut from local limestone, basalt, jasper or oil shale"…"Sometimes glass *tesserae* were used for rare colours such as green and blue"…Piccirillo (1993) 19–23.

2. Wall Plaster and Mural Paintings

Although very few mural paintings have been preserved from the Umayyad period, they are significant because of the motifs and scenes they portray. These vividly depict the life and customs of the new Umayyad rulers. The best preserved and most famous are undoubtedly those from Qusayr ʿAmra (fig. 2).[60] Traces of similar murals have been discovered in other Umayyad palaces, like the complexes of Qasr Hallabat, the Hammam at Sarraj,[61] and Qasr el Hayr East and West (which also has important floor paintings.)[62] Although usually referred to as *frescoes*, they were actually painted *a secco*, i.e., the pigments were diluted in a lime-based media and then painted onto a mortar layer that had been applied at an earlier stage. These paintings were still created using the Roman technique of applying the paint onto a fine layer of white lime (*intonaco*) which, in turn, covered a thick levelling layer (*arriccio*) of lime plaster—usually consisting of a poor quality lime with ashes. A herring-bone pattern was sometimes incised into the surface of the preparatory plaster. This would, during the Umayyad period, in many cases, be combined with, or sometimes replaced by, crushed basalt stone or gravel, offering an even better hold for the final plaster layer. Examples can be found at Umm Al-Walid, Qasr Hallabat, and another variant at the Amman Citadel mosque.[63]

3. Carved Stucco

Gypsum plaster and stucco were used in building work because they were cheap, easy to work with, flexible and versatile. They could be used in three-dimensional sculptures, decorative panels, window grills and, as seen above, load-bearing elements. Their widespread adoption in the Umayyad period solved the huge and pressing demand for construction work. Once again, the merging of techniques and formal repertoires generated a novel, hybrid result.

The main distinction between Sassanian and Umayyad stucco is that the first was mostly stamped onto plasterwork with moulds, whether directly onto walls, or onto serial manufactured tiles (fig. 13), or moulded

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[60] Almagro *et al.* (1975).

[61] Bisheh (1980) and Arce (2006a).

[62] Creswell (1969).

[63] See Arce (2006a) and (2002). Note that these methods are the same as those employed in 'standard', rather than 'decorated', plastering.

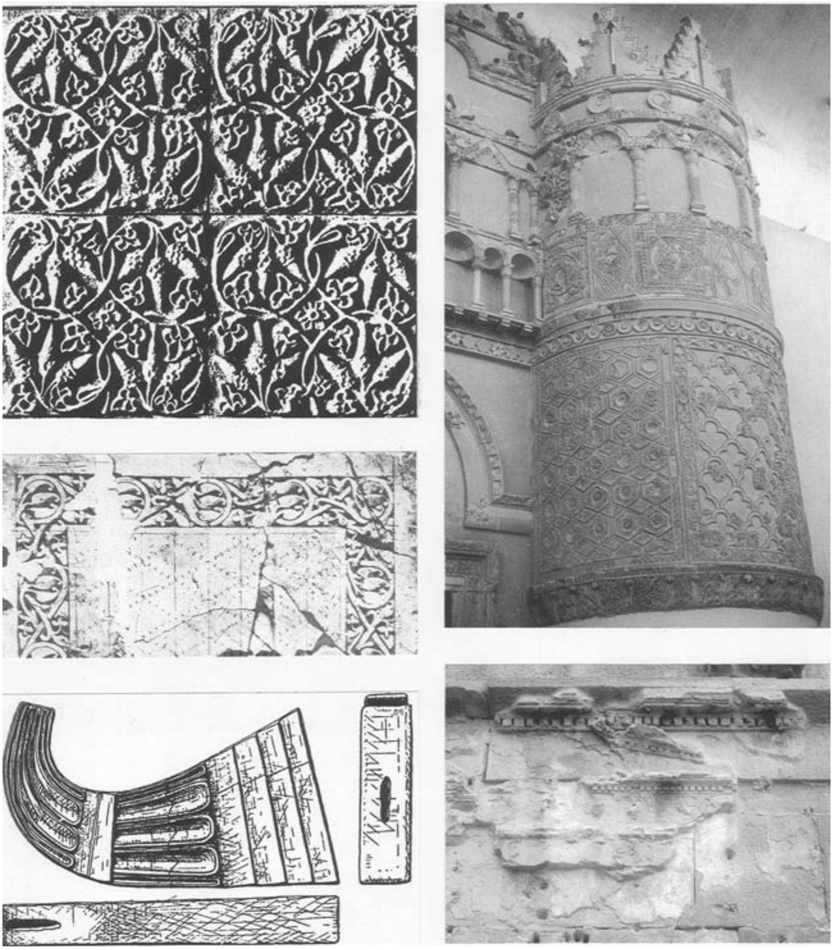

Fig. 13 Stucco. a: Sassanian pre-cast or moulded gypsum plaques (true antecedents of decorated wall tiles); b: Qasr al-Hayr al Gharbi (Syria) Main entrance. Stucco panels applied in a 'wallpaper fashion', with disregard to the structure on which it is laid upon; c: Khirbat al-Mafjar. Unfinished chiselled stucco panel (From Hamilton (1959)); d: Sassanian stamps for stucco; e: Petra. Qasr al-Bint Hellenistic-style stucco architectural lining.

plaques.[64] In contrast, the patterns of Umayyad stucco were mostly carved manually onto the plaster while it was still soft.[65] In this case, as with the *giornate* of *fresco* paintings, it was necessary to apply only as much plaster as could be decorated in one day. Thus, joints can always be traced in the finished painting. Nevertheless, free-hand carved stucco can also be found in Sassanian architecture, and in the moulded plaques and stamps of Umayyad buildings. The decorated roundels at Qasr Harane serve as an example of the latter.[66]

The standard Umayyad technique usually comprised the insertion of levelling layers of lime mortar plaster (similar to those used in mural paintings and wall rendering) under the final gypsum-plaster layer. Once again, this is an example of a 'technical merging' of Sassanian and classical practices.[67] Before it dried and hardened, the final layer of gypsum-made stucco was carved and modelled directly onto the hardening plaster with a blade, or putty knife. The *chiaroscuro* effect was reinforced with holes that were drilled into specific points (piercing beads or, where the main lines of the design changed direction, the stems and branches of leaves). The carving was most probably carried out with a triangular, in-section chisel, knives and drills. Consequently, the results of this craftsmanship are more expressive than the ornamental pieces of stiff plaster stamped with moulds.

The firmly-established tradition of stone-carving in Byzantine Syria must have influenced some of the techniques responsible for Umayyad carved stucco. It is possible that these were technically superior to those employed within the Partho-Sassanian tradition. The use of precisely-drawn guidelines in geometric patterns bears this out. It is probable that some of the Sassanian 'all encompassing' (or 'infinite') geometric patterns were also executed by using preparatory drawings. However, the abandonment of stamping moulds and the very articulated architecture within which these were applied, necessitated the improvement of these preparatory drawings.

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[64] Arce (2001a) fig. 3 and Baltrusaitis (1939).

[65] For a complete review of these features, see Arce (2001a): "The Early Islamic Stucco Technique and the Partho-Sassanian Tradition."

[66] Urice (1987) figs. 89 and 91. Once more show how closely this building related to original Sassanian technical traditions.

[67] This mixed technique sometimes made it difficult to attach the final layer of decoration, due to its weight and the insufficient grip provided by the incised herringbone-pattern keys. This often caused the detachment and eventual collapse of complete sections of panels.

Attempts to adapt decorative patterns to architectural structures can also be identified. In our opinion, this represented the main contribution of Syro-Byzantine craftsmanship, and determined the 'westernised' character of this eastern technique. Nonetheless, it should be noted that, in most of the cases, the traditional lack of correspondence between decoration and structure, inherited from the Persian tradition, was still predominant (fig. 13).

According to Hamilton, who studied the unfinished panels found at Mafjar, the instruments used in the preparatory drawings included a ruler, a scoring tool, a blunt point, dividers and a taut string. Most of the base drawings were composed of equilateral triangles. Others were drawn on squares, parallel to each other, tilted 45 degrees, or etched into inter-laced and equal circles.[68] Despite the use of preparatory grid base-drawings, the geometric pattern was eventually applied with little attention to the edges that framed it. Therefore, in order to obtain a neat finish, the pattern was surrounded by a sort of frame that closely resembles the geometric, or 'infinite', patterns found on oriental rugs (fig. 13). It is also reminiscent of the use of wallpaper, or textiles, as wall linings (Hamilton very accurately uses the term 'wallpaper treatment' to describe the result). Hamilton points out that the main difference between the use of similar 'infinite' patterns by Christian Syrian sculptors and their Umayyad counterparts is that the former always adapted their pattern to the proportions of the field, so that 'no fraction of a unit was left over the edges'.[69] The procedure followed by the Umayyads had its origins in the original Sassanian stucco tradition, which used mould-stamps and tiles, or moulded plaques. When a repetitive pattern was applied by means of a stamp (or when pre-cast plaques were used as a cladding), a preparatory drawing was not necessary, as the mould or stamp was printed repeatedly onto one field until it was completely covered. Inevitably, fragments of the basic unit were left on the edges of the field.

The traditional Syro-Byzantine procedure and concept design can only be detected in some of the pre-fabricated balustrade panels from Mafjar (fig. 13). It corresponds to the stone-carving techniques displayed by the marble-carved screen panels, in which the design was composed within a field, and was treated as if it had been framed, and the design composed precisely within it.[70] In such cases, it seems that the panel was not carved, or chiselled, while it was still soft, but was first left to dry completely. In the panels found at Hallabat,[71] an intermediate approach can be detected: Sassanian techniques were used to execute a Syrian design, consisting of panels which were framed and articulated by architectural elements. Such designs were thus more closely related to the architectural support. The co-existence of both methods, and the merging of concepts in the architectural features of one building, again reinforce the hypothesis that Syrian and Mesopotamian craftsmen were working together, sharing and interchanging experiences and knowledge in order to reach a new and unique result: the synthesis of two cultural and artistic traditions.

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[68] Hamilton (1959) 273 and plates LXI & LXII.

[69] Hamilton (1959) 280.

Conclusion

The experimental process of merging of western and eastern architectural models and building techniques during the Umayyad period contributed to a new architectural and urban tradition that was to liberate Islamic material culture from Antiquity. It can be seen as one element of a general process of transformation, driven by the attempts of Umayyad rulers to establish new administrative, political and economic frameworks in place of those inherited from Late Antiquity.

It is important to note that this combination of artistic trends provided a new catalogue of techniques and styles that defined the emerging culture (and its corresponding image of power) and, at the same time, guaranteed the survival of 'antique' cultural practices and elements from the eastern and western traditions that would otherwise have been lost. This balance between continuity and change is particularly striking in the case of the city. Here, an 'urban culture' was preserved thanks partly to the transformation process it underwent, and partly to the strong monetary economic system that was developed. Far from neglecting the 'classical city', these factors led to its revival and transformation in the Near East.

The strength of the new and hybrid culture triggered transformation elsewhere in the Mediterranean basin. Indeed, a similar transformation from Antiquity to a new era took place in some other areas under Islamic control, such as in Spain (al-Andalus).

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[70] Hamilton (1959) 280.

[71] Restored by the author.

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All pictures and drawings (except where stated otherwise) by the author.

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Glossary

Adobe. Sun-dried mud brick.

Anathyrosis. Joint surface treatment by which the perimeter of the faces of each block or element is finely carved and smoothed to provide a neat and precise joint with the neighbouring block. In the case of ashlar carving, anathyrosis usually adds to the visible face of the block a recessed perimetral surface band, while the rest of the block face is usually not carved so accurately, or is even left with a rough and protruding finish. In this case, we have ‘rusticated ashlar’, and ‘rusticated masonry’ work. Where column drums, or other linear, load-bearing elements, are concerned, the internal area of the smoothed perimeter band of the hidden face of the joint is carved away, leaving a hollow void. By doing this, the load is evenly transmitted simply by means of the smoothed perimeter band, avoiding the harmful occurrence of local tensions and the concentration of stress that can create cracks and even provoke the collapse of the structure.

Apadana. Building used for royal receptions by the Achaemenid kings. This kind of audience hall consisted of a huge square room covered by a flat roof, which was made of wooden architraves and supported by a ‘forest’ of columns placed on a regular and orthogonal grid pattern. The most famous example is that built by Darius I (522–486 B.C.) and finished by Xerxes at Persepolis, and the oldest one, that from *Pasagardae*, dated to the 3rd quarter of the 6th c. B.C.

Ashlar. Prismatic-shaped, carved stone block.

Barrel vault. Linear vault with a semi-circular section.

Centring. Provisional structure to support the single components (*voussoirs*) of an arch or vault until it is closed and thus support itself. It can also be applied to structures supporting a formwork.

Chiaroscuro. Sharp, contrasting shading, drawn by strong light on the moldures, surfaces and volumes of an object.

Cloister ***(or ‘skif’) Vault.*** Compound vault in which barrel vaults intersect and form a pyramid-shaped, curbing ceiling.

Colonnettes. Small decorative columns with no structural function.

Conoid. Three-dimensional surface defined by straight lines stemming from a point (or even a straight line), and resting on a curve that serves as a guideline.

Corbel. Cantilevered support, or bracket.

Diaphragm Arch. Structural arch placed transversally in a room; intended to reduce the span that is to be covered afterwards with beams or barrel vaults.

Dog-teeth (also Saw-tooth) cornices. Moldure of Sassanian origin, consisting of a series of triangular elements that can be displayed in a linear design along cornices of springing lines, architraves, etc., or in a circular fashion around the perimeter of an arch.

Emplekton. Core filling of a two-face ashlar masonry work, consisting of rubble mixed with mortar. The term was eventually to define the building technique itself.

Extrados. The outer (convex) surface of vaults and arches.

Formwork. Provisional encasing device to contain and give shape to an element built with a fluid material (concrete, plaster, earth, etc.) before it becomes stiff and self-standing.

Groined (or Cross) Vaults. Compound vaults in which barrel vaults intersect, forming ridges called *groins*.

Headers and Stretchers. In masonry, the elements (bricks or ashlars) laid, respectively, across and along the wall.

'High-flame' Lime Kilns. Kilns in which the heat required to 'cook' the limestone is provided by inefficient fuel (timber) that burns quickly with flame, in a firing chamber placed underneath the upper chamber where the stones to be burnt are placed in a dome-like fashion.

Horseshoe Arch. Ultra-semicircular arch in which the curves are carried below the theoretical springing line (the ends of its horizontal diameter), so that the opening at the bottom of the arch is less than its greatest span.

Intrados. The inner (concave) surface of vaults and arches.

Iwan. Large vaulted hall in which one of the end sides opens onto a courtyard through an arch, which has the same section and span as that of the vault. Prevalent in Parthian, Sassanian and Islamic architecture.

Lintelled Structure. Ceiling structure devised with architraves or beams, not arches or vaults.

Lintelled Squinch. Squinch built with beams, or architraves, placed in the corners of a room.

'Low-flame' Lime Kilns. Kilns in which the heat required to 'cook' the limestone is provided by highly efficient fuel (pine cones, olive pits and nut shells) that burns slowly with no flame. They contain a single firing chamber in which combustible materials and stones are placed in alternate layers.

Pendentives. Curved wall surfaces, which form a transition between a dome and its supporting structure. Usually, spherical triangles result from the intersection of a half sphere with (4) vertical planes, traced in correspondence with the arches that support the dome, and a (fifth) horizontal plane which corresponds with the springing line of the dome, or drum they support.

***Pisé* (also *Tapial*)**. Building technique used for the construction of walls with rammed earth contained within a wooden and re-usable formwork.

Pitched-Brick Vaults. Vaults in which the rows of bricks are laid vertically, or at a slight inclination, leaning against the row previously laid (the very first one leans against the end wall), thus obviating the need for a centring.

***Pointed Arch* (or *Two-Centred Arch*)**. Arch defined by two symmetrical sections of circumference, the centres of which are placed separately on the springing line. The distance between the centres defines how acute the pointed arch is. In the first examples, from the Umayyad period, the distance between centres varies from one-tenth to one-seventh of the span of the arch. Later, in the Gothic period, this distance would increase, becoming equal to, or even bigger than, the span of the arch itself, which became increasingly acute.

Polylobed Arch. Arch with a compound profile defined by a series of smaller ultra-semi-circular arches, placed alongside the main interior profile of an arch. These smaller, decorative arches (*lobes*) are usually carved out of the interior surface, but also protrude in some cases.

***Pry Marks* (or *Prise Marks*)**. Holes left on the faces of huge ashlars that were used to place levers, designed to move the upper course ashlars.

***Sail or Spherical vaults* (also *Pendentive Domes*)**. Vaults resulting from the intersection of a spherical surface with vertical planes. Also, domes with inner surfaces (intrados) continuous with the surfaces of their pendentives.

Squinches. Arches or transitional elements (corbeled architraves, half-cones or *conoids*) that span the interior corners of a square structure, serving to support a circular or polygonal superstructure, for instance, a dome, or a drum with a dome.

Squinch Vault. Vault created by the intersection of 4 or more *conical* squinches, defined by increasingly wider rings of pitched bricks, which span as much space as required to cover the whole of the room.

Stereotomy. Process of cutting solid material, such as stone, into certain volumetric shapes or figures. It is applied to the cutting from cubic blocks of quarry stone into complex elements, such as *voussoirs* and other elements from arches and vaults.

Suspensurae. Elevated floors of heated rooms (*caldaria*) in Roman baths, built over a heated chamber (*hypocaustum*) and supported by brick or stone structures (*pilae*).

Tectonic feature. Structural, load-bearing element.

Triconchs. Triple-apsidal hall, usually placed at the end of a basilical/linear space. The term can define the hall or the whole building that contains it.

Voussoir. Masonry wedge-shaped element that forms an arch or vault.

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LATE ANTIQUE ARCHAEOLOGY

Series Editor

LUKE LAVAN

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